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ELECTROMAGNETIC ANTENNA MODELING (EAM) SYSTEM

Science Applications International Corporation

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13. ABSTRACT (Maximum 200 words)
The determination of foreign communications capabilities and intent is an important assessment function performed by the USAF National Air Intelligence Center (NAIC). In this context, Rome Laboratory became the NAIC engineering agent for the development of an NAIC requirement for the rapid analysis and evaluation of antenna structures based on often vague to sometimes detailed dimensional information. To this end, the Rome Laboratory sponsored development of the Electromagnetic Antenna Modeling (EAM) System, a state-of-the-art Pascal program with an MS Windows Graphical User Interface (GUI) pre- and post-processor. Users of NAIC capabilities initiate antenna analysis efforts that range from simple parametric studies to more complex, detailed antenna-design and communication-system evaluations. Accordingly, EAM provides a modeling capability "matched" to the sophistication of the individual analyst, with features appropriate for users ranging from non-technical analysts to experienced antenna engineers. This capability is particularly valuable in the military-intelligence environment, in which high-speed assessments are required. In particular, EAM meets the specific antenna-analysis requirements of NAIC with a versatile graphical user interface.

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EXECUTIVE SUMMARY

Introduction

The determination of foreign communications capabilities and intent is an important assessment function performed by the USAF Foreign Aerospace Science and Technology Center (FASTC). In this context, Rome Laboratory became the FASTC agent for the development of a FASTC requirement for the rapid analysis and evaluation of antenna structures based on often vague to sometimes detailed dimensional information. To this end, the Rome Laboratory sponsored development of the Electromagnetic Antenna Modeling (EAM) system. EAM is a state-of-the-art Pascal program with an MS Windows Graphical User Interface (GUI) pre- and post-processor. Users of FASTC capabilities initiate antenna analysis efforts that range from simple parametric studies to more complex, detailed antenna-design and communication-system evaluations. Accordingly, EAM provides a modeling capability "matched" to the sophistication of the individual analyst, with features appropriate for users ranging from non-technical analysts to experienced antenna engineers. This capability is particularly valuable in the military-intelligence environment, in which high-speed assessments are required, but personnel turnover and organizational down-sizing limit the learning curve. Thus, the EAM system was designed for the versatility needed to match antenna analysis capability to the composition of the work force. In particular, EAM meets the specific antenna-analysis requirements of FASTC with a versatile graphical user interface (GUI).

Many numerical-analysis computer programs have been developed for antenna analysis. Some of these programs employ simple modeling techniques for rapid analysis of well-known antenna structures, such as dipoles, yagis, log-periodic arrays, etc.. Other programs are intended for detailed analysis of arbitrary or complex antenna-system designs, such as vehicle or building mounted custom-designed antenna structures. EAM integrates the virtues of both approaches into a single cohesive software package designed to meet FASTC's various user requirements. In this regard, the EAM system consists of three program modules designed and developed specifically for the analysis and design of antennas. The first module provides quick parametric analysis and is designated the Quick-Look module. The second module, Fine-Grain Radiators, provides rigorous analysis and design of antennas that are less than a few wavelengths in size. The third module, Fine-Grain Scattering, provides rigorous analysis and design of antennas that are greater than a few wavelengths in size. The entire system runs on the 80386/486 PC architecture with Windows™ 3.0 or higher running in enhanced mode.

The Quick-Look module uses closed form and simple Moment-Method (MM) solutions to perform quick parametric studies of twenty different standing-wave, traveling-wave, and aperture antenna types. Since computationally simple solutions are used, predictions for each of the twenty antenna types can be obtained within several seconds. The Fine-Grain Radiator module provides the capability of analyzing an antennas in-situ using a GUI that employs the Numerical Electromagnetics Code

(NEC) developed at Lawrence Livermore National Laboratory. The GUI includes a 3-D antenna drawing package, user-friendly dialog boxes, NEC execution interface, and the visualization software to rapidly view polar radiation patterns and color current-intensity diagrams. The Fine-Grain Scattering module provides the capability to predict scattering for electrically large objects using a GUI employing the Numerical Electromagnetic Code-Basic Scattering Code (NEC-BSC) developed at ElectroScience Laboratory. The Fine-Grain Scattering GUI includes a 3-D drawing package, user-friendly dialog boxes, NEC-BSC execution interface, and the visualization software to rapidly view Cartesian electric field and radiation patterns versus take-off angle or frequency.

The EAM System

Quick-Look Module. The Quick-Look module contains a user-friendly GUI combined with analysis software to predict the performance of twenty different antenna types of typical interest to FASTC users. The GUI allows for quick specification of each antenna's physical dimensions for parametric studies. The principal advantage of the Quick-Look module derives from the rapid computation (CPU) time required for each antenna analysis. These CPU-time requirements vary from pseudo-instantaneous to 39 seconds on a 80486-based PC running at 33 MHz (see Fig. 1). The numerical antenna-analysis approach depends on the particular antenna type under study, with all twenty algorithms described as either closed-form, simple MM, or superposition solutions. Quick-Look also includes an arraying feature that allows each antenna to be used as an element in a three-dimensional antenna array.

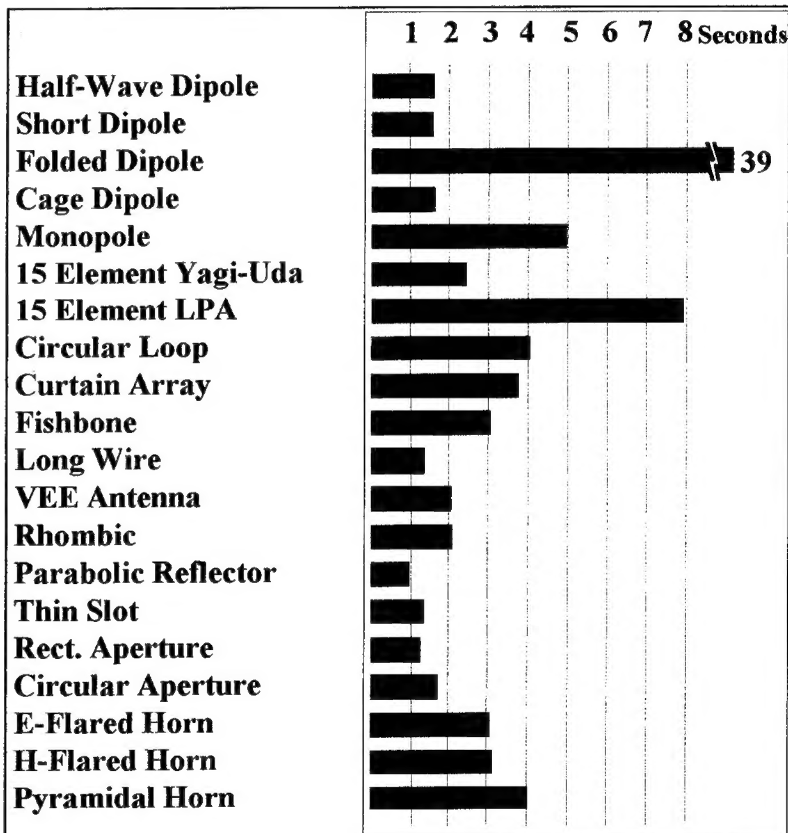

Fig. 1 Quick-Look Execution Time for Each Antenna Type

Each antenna type within the Quick-Look module has four windows used for input and output as shown in Fig. 2. Tailored to each antenna type, the input window allows the user to describe physical dimensions, excitation characteristics, and other measured quantities. The user can enter a specific value or use a default option.

Defaults appear for each parameter and can be used as a guide or tutorial for a "typical" antenna. An additional "user-friendly" feature is instant error checking. If an out-of-range or invalid value is entered, the GUI will alert the user to this error and provide assistance in choosing acceptable values. All functions in this window can be performed with either mouse or keyboard input.

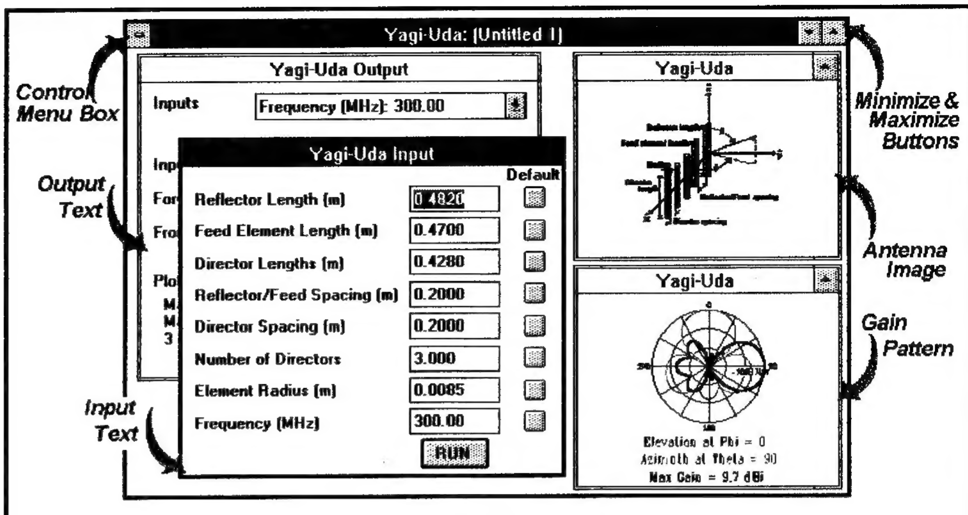

Fig. 2 Typical Quick-Look Module Display

A diagram of a chosen antenna type is displayed to the "right" of the input window. This diagram serves as a reference for all required physical input parameters such as length, radius, and height. If the user is unfamiliar with an antenna, its diagram can be enlarged to show greater detail or reduced to create more workspace. Outputs of the analysis are displayed in two separate windows, one window containing specific calculated quantities, and the second window displaying a radiation pattern plots. The text output window displays calculated parameters such as maximum gain, half power beamwidth, radiation resistance, etc. In addition, it re-displays the input parameters used in the analysis. The radiation-pattern window contains calculated pattern data for any user-specified plane of view. The user is given the option to view an elevation pattern, azimuth pattern, or both. The plots can also be displayed in either a Cartesian or polar coordinate system. As with the antenna image, the radiation-pattern screen can be enlarged or reduced by the user to the desired size for viewing.

The Quick-Look module GUI also uses the Windows™ Multiple Document Interface (MDI) to allow several windows to be displayed simultaneously. This feature allows performance comparisons to be made for many different antenna types or for multiple design variations of a single antenna type. In addition, a detailed context-sensitive "help" system and custom-menu items such as "Tile Patterns", "Bring Window to Top", and "Select Defaults" simplify operation and enhance utility.

Fine-Grain Radiator Module. The Fine-Grain Radiator module provides complete wire and patch antenna analysis using a GUI for NEC. NEC is recognized as a gold-standard in MM codes and is used for predicting the performance of antennas less than a few wavelengths in size. Its core computation is the current distribution on a segmented wire/patch model. Computational time is directly related to the electrical size and segmentation of the antenna model. NEC, like most text-based engineering

tools, is user unfriendly and requires extensive knowledge and experience to be used correctly and effectively. The GUI includes a 3-D antenna drawing package to help the user visualize the antenna model, check for input errors, and specify NEC execution-control parameters. Finally, the Fine-Grain Radiator module displays polar radiation patterns and color current intensity diagrams.

As seen in Fig. 3, the Fine-Grain Radiator module includes a *menu* bar, *tool* bar, *drawing* window, and model *statistics*. The menu bar in the main window allows access to file management operations, executes NEC, displays output plots, manipulates windows, and accesses "Help" windows. The "File" menu item allows a user to "open" one or more antenna definition/drawing windows. These windows input numerical data stored in NEC input files and display this data as 3-D images to support the creation, viewing, editing, and printing of arbitrary antenna models. The "Run" menu item is used to execute NEC "transparent" to the user. During NEC execution, a rotating wheel is displayed to signify that an analysis is in process. Finally, the "Plot" menu item controls the generation of output plots, such as polar radiation plots and current intensity diagrams. The "Window" menu item provides conventional window manipulation functions such as "Cascade", "Tile", "Arrange Icons", and "Close All Windows". The "Help" menu item provides assistance in the use of all GUI features and options.

A key feature of the Fine-Grain Radiator module is the "antenna definition" window. The window was designed to have the "look and feel" of a typical Windows™ vector-based drawing package with additional features for displaying 3-D images. This 3-D drawing package automates the tedious work of defining and typing wire coordinates in a DOS text file by providing full 3-D mouse movement. As shown in Fig. 3, the antenna definition window contains a window title, drawing area, wire and view manipulation tools, scroll bars, and drawing information.

An important feature of the Fine-Grain Radiator GUI is the method employed for "wire" definition. Defining a wire using the antenna-definition

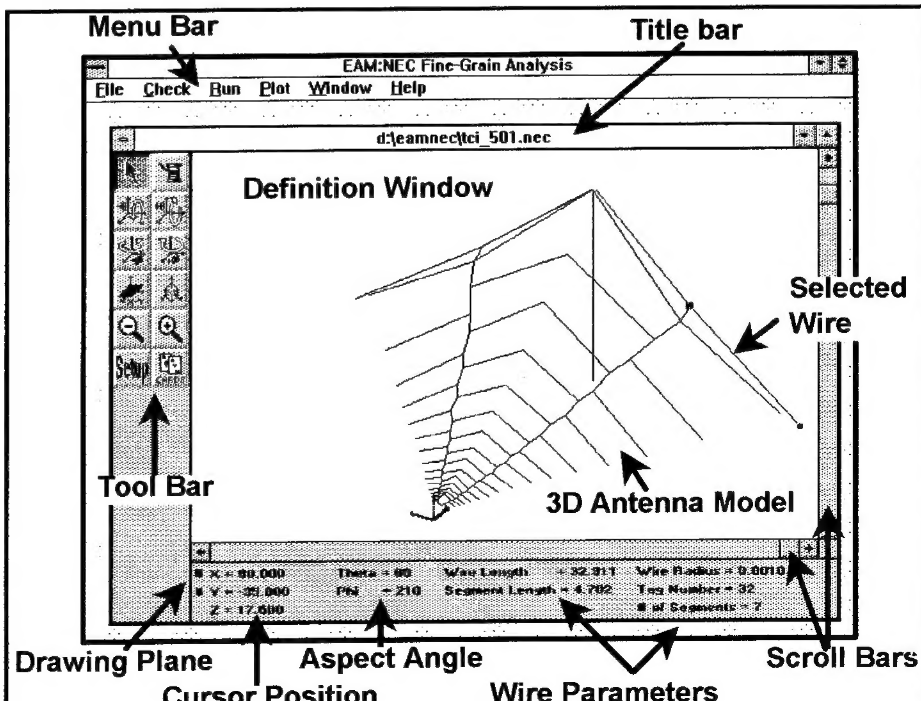

Fig. 3 Example of a Single Antenna Definition Window

window is similar to drawing a line in commercial graphics software packages. Wires are drawn simply by "clicking" the left-hand mouse button at the wire start point (coordinate), then "rubber banding" the wire to the desired wire end coordinate, and then releasing the mouse button. The wire is displayed on the screen and its start/end-point coordinates are stored in memory for subsequent creation of a NEC input file. An existing wire can be edited by using the "Arrow" tool to "stretch" or "shrink" the wire from either of its endpoints in a similar fashion. Connecting two wires requires that the connecting ends have identical 3-D floating point coordinate values. This connection is not easily accomplished when converting mouse cursor locations to 3-D coordinates, because the distance between screen pixels is often much larger than the resolution of a floating point number. The antenna-definition window provides four features to ensure precise wire connections: "Snap-to-Grid," "Wire-Segment Find," "Wire-End Find," and "Display segmentation". "Snap-to-Grid" restricts the cursor movement to a user-defined 3-D grid resolution. "Wire-Segment Find," activated with the "F" key, sets the 3-D cursor coordinates to match those of the closest wire segment end. "Wire-End Find," activated with the "*Shift* F" keys, sets the 3-D cursor coordinates to that of the closest wire end. Displaying wire segments is accomplished on a selected wire by depressing the "S" key, or for the entire model by depressing the "*Shift* S" keys.

The GUI enables the antenna model to be quickly viewed from any point specified in spherical coordinates, that is, any (r,θ,ϕ) location. This feature is accomplished using "scroll bars," "zoom buttons," and "orientation buttons". Scroll bars are used to change the location of the 3-D origin on the screen. Zoom buttons enable a user to enlarge a portion of a model to show more detail or shrink the display to show more of the model. Coordinate system orientation buttons allow a user to view a model from any (θ, ϕ)-aspect angle. Each time a button is pressed, θ or ϕ value is incremented or decremented by a user-specified amount. After definition of model wires, NEC execution "control lines" for excitation, frequency, and desired output must be specified. The Fine-Grain Radiator includes a control-line editor that simplifies specification of most NEC execution parameters. A "Miscellaneous" line allows the use of control lines not recognized by the line editor, such as "upper medium," "dielectric sheath," and "print control". The experienced user can use the "Miscellaneous" line to create any desired execution-control line.

NEC execution is performed by selecting the "Run" menu item. NEC will automatically create and save an input file for the active drawing window and then execute the NEC program with this input file. Once an analysis has begun, the cursor changes to a rotating wheel to signify that execution is in progress. At this time, the user can employ the Windows' multi-tasking feature to initiate a second Windows™ application, such as, a word processor, spreadsheet, etc. The Fine-Grain Radiator GUI will execute using both an unmodified NEC-2 FORTRAN version from the NEEDS package or NEC-3i compiled for a DOS PC. The GUI reads the NEC-generated files for desired information and plots the data in the form of polar radiation plots and color-coded current intensity diagrams. The GUI can display data obtained from existing NEC output files as well as output files generated on a main-frame computer. "Huge"

NEC models can be created with the GUI and then transferred to a main-frame computer for faster execution The resulting NEC output file can then be transferred to the PC for graphical display.

Figure 4 shows a sample of polar radiation plots generated by the Fine-Grain Radiator GUI. Both elevation and azimuth patterns can be displayed individually or together on a single polar plot. The two patterns are distinguished by both line color and thickness. The elevation pattern is shown as a solid "red" line, while the azimuth pattern is shown as a dashed "blue" line. Selection of a specific ϕ (θ) angle for the elevation (azimuth) pattern is performed from the "Plot-Options" menu item. Color-coded current-intensity diagrams graphically display NEC-output current intensity predictions superimposed in color on the wire model of the antenna system (see Fig. 4). Red (hot) is used for segments with the highest current density, while blue (cold) indicates lowest current density. The value associated with each color can be determined automatically or specified by the user.

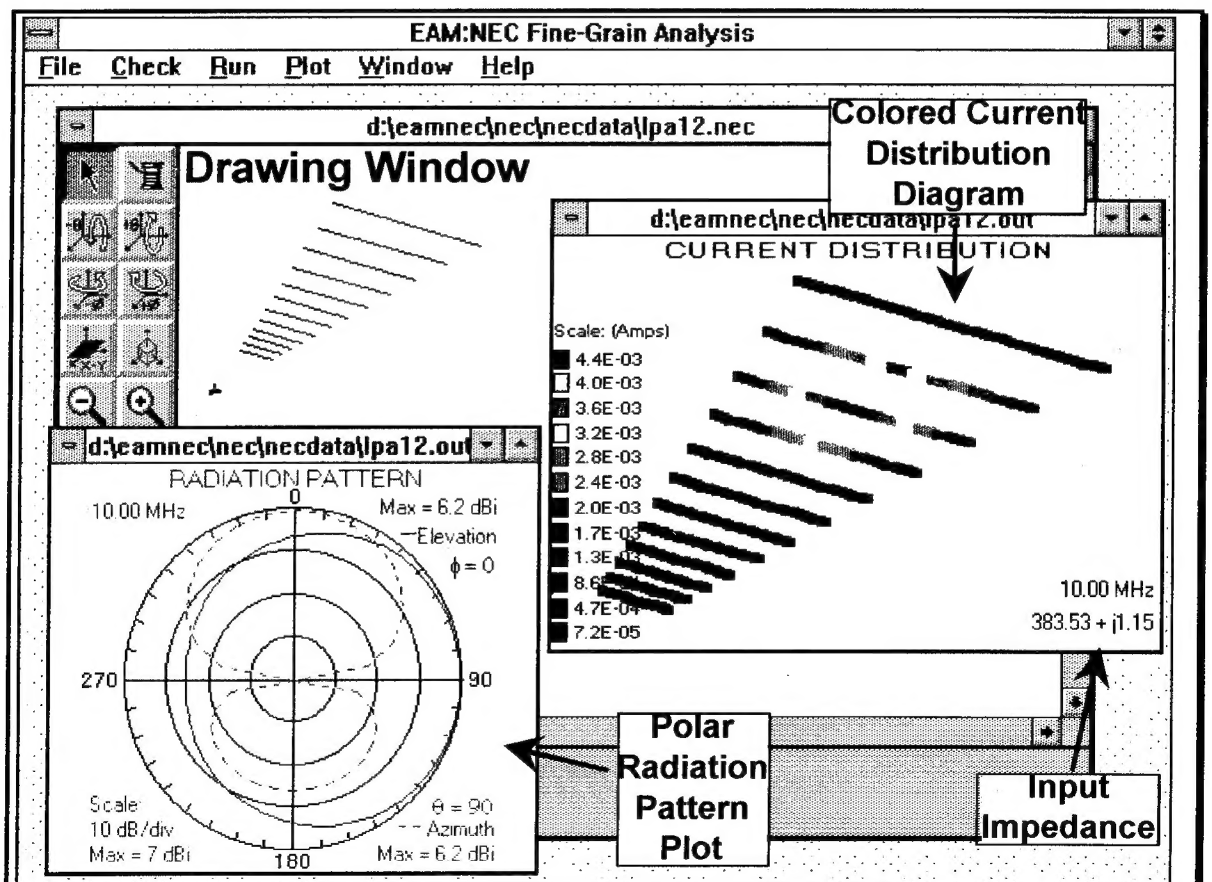

Fig. 4 Multiple Windows Showing Model Geometry and NEC-Computed Output

Fine-Grain Scattering Module. The Fine-Grain Scattering module provides predictions of electromagnetic scattering from electrically "large" objects using a GUI that executes the Numerical Electromagnetics Code-Basic Scattering Code (NEC-BSC). As with the Fine-Grain Radiator module, the GUI includes a 3-D drawing package, user-friendly dialog boxes, NEC-BSC execution interface, and the capability to rapidly reduce and display NEC-BSC output data. NEC-BSC, developed by Ohio State, is based on a uniform asymptotic technique formulated in terms of the Uniform Geometrical Theory of Diffraction (UTD). Electrically large structures, greater than three wavelengths in diameter, are simulated using structures such as plates, cylinders, ellipsoids, and cone-frustums. Principal output data include electric and magnetic fields strengths as well as radiation patterns. Although NEC-BSC is capable of frequency sweeps, it does not calculate surface currents so impedance data are unavailable. This version of NEC-BSC was modified slightly to compile in MS Windows using MicroSoft FORTRAN 5.1. In order to retain the original capabilities of version 3.2, a DOS-executable version could not be created without exceeding the 640-K barrier. This limitation was bypassed by compiling this software for Windows-based execution to an executable size of 1.1 MBytes.

The general "look" and functionality of the NEC-BSC GUI shown in Fig. 5 is identical to that of the NEC GUI. The tool bar, however, has been modified to support NEC-BSC requirements. Within the tool bar, the view-manipulation tools are identical to the NEC GUI. New tools were introduced, however, for drawing the various model structures. These new tools are used to draw plates and cylinders and to locate sources and receivers. The remaining structure-geometry tools will be added to subsequent versions of the GUI. The existing GUI features were tailored for the novice user, designed for simplified model specification using intuitive operations. As in the NEC GUI, a control-line editor has

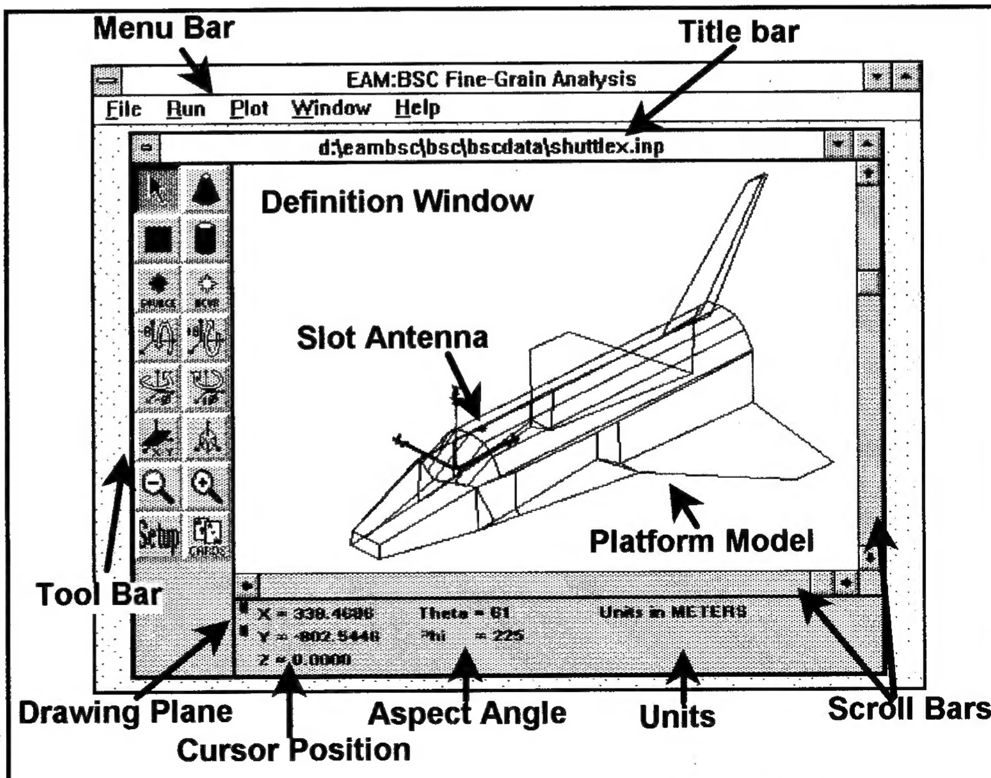

Fig. 5 Example of EAM-BSC Antenna Definition Window

been designed and customized for BSC. This editor enables the user to employ those BSC features not currently provided by the GUI.

Windows™ PC multi-tasking enables the user to perform a variety of tasks during "transparent" execution of NEC-BSC. This feature permits the user to operate other applications while NEC-BSC is executing. To display user-specified results, output files created by NEC-BSC are scanned automatically by the GUI. The user can choose a specific "data pattern" from a list derived from the output file. The GUI then reads the required data into memory for display in Cartesian plot format. These plots are automatically scaled and include texture and color-coded detail. It is important to note that although the original output file is "read" by the GUI, it is not altered in any way. As a result, the Fine-Grain Scattering module, as well as the Fine-Grain Radiators module, is capable of reading and editing pre-existing NEC-BSC, and NEC, input and output files, respectively.

Summary and Recommendations

An antenna-analysis package has been developed for use by both novice and experienced EM engineers and analysts. A user with only a basic understanding of PCs and Windows™ will be able to use the EAM software to predict the performance of any antenna structure. This broad range of application is achieved by combining a unique selection of available algorithms with a user-friendly GUI. The package uses closed-form solutions to allow an analyst to perform quick parametric studies of generic antenna types. It also uses state-of-the-art MM and UTD codes to model virtually any antenna structure in detail. The Windows-based GUI automates the otherwise tedious and potentially confusing methods required to define an antenna structure and view analysis results. It includes context-sensitive on-line help, error checking, three-dimensional drawing capability, and easy-to-understand output plots. EAM was coded in Turbo Pascal for Windows on an 80486-based PC with eight megabytes of RAM and VGA graphics. It executes in an MS-DOS 5.0 and Windows 3.0 (or higher) environment. Although the package can be used successfully on an 80286-based PC with EGA graphics, it will have reduced capability due to slower computational speeds, reduced screen resolution, and limitations on the Windows' standard mode.

Although the EAM software represents an innovation in antenna modeling and analysis capability, experience with the completed package has led to the identification of several worthwhile software modifications and additions.

Modification to the EAM-QL version 1.0 should include:

- additional antenna types,
- transmission line windows,
- allow user defined array excitation,
- improved plotting window,
- the effect of real grounds.

Modifications to the antenna drawing (CAD) portion of EAM-NEC version 1.0 should be performed to provide the capability to:

- draw and edit surface patches,
- duplicate and insert wires,
- re-segment the model based on a specific tag number,
- display total number of wires and segments in the "information" window,
- check for connected/disconnected wires,
- query the user before saving a NEC file before user-directed NEC execution,
- execute the current NEC 4 code from within EAM-NEC,
- move multiple wires via tag number with a dialog box,
- save user preferences in an ".INI" file,
- recognize the GX (symmetry) card and display virtual elements in a different color,
- include GFI NEC documentation in the existing "HELP" system,
- perform model integrity checks via the main menu, including,
  - duplicate wires
  - overlapping segments/patches
  - wires intersecting at wire and segment ends
  - wire segmentation relative to wavelength
  - large delta in segment length between connected wires
  - wire radius relative to wavelength
  - wire radius relative to segment length
  - large delta in wire radius between connected segments
  - acute angles
  - wire to patch connections
  - patch size relative to wavelength
  - patch segmentation
- visual representation of patches as colored solids,
- recognition and display of the HX (Helix) card,
- addition of a customized dialog box for editing the HX card,
- improvements to the text editor to handle large NEC output files,
- addition of customized building blocks to enable faster model development,
- visual representation of a ground plane as colored (shaded) object,
- hard-copy output improvements for the display of models, plots, etc.,
- visual representation of the wire radius with dimensional adjustments scaled to the user-selected magnification.

Modifications performed on the control line-editor portion of EAM-NEC should be added to include the following capabilities and features:

- recognition of the CM, CE, GM, GR, GS, and GX structure geometry cards,

- functional presentation of customized dialog boxes for the CM, CE, GM, GR, GS, and GX cards,
- functional presentation of customized dialog boxes for the GD, LD, NE, and TL cards.

Modifications to the post-processor portion of the EAM-NEC should be added to include the following capabilities and features:

- improvements to the existing polar-plot format,
- addition of Smith-chart format for plots of impedance data,
- addition of a linear-plot format for all output values,
- power gain, E-field, near field, and VSWR data presentation in linear-plot format,
- improvements to the existing current intensity-diagram format,
- addition of a three-dimensional radiation pattern plot format for the display antenna pattern data.

Modifications performed on the antenna drawing (CAD) portion of the EAM-BSC software should be added to provide the capability to:

- draw and edit cone-frustum geometry,
- visually verify the position and orientation of the source and receiver,
- duplicate and insert model structures,
- query the user before saving a BSC file before user-directed BSC execution,
- visually represent structures as colored solids,
- draw and edit ellipsoid geometry,
- visually verify the path of source and receiver movements,
- move multiple structures simultaneously with a dialog box,
- save user-preferences in an ".INI" file,
- employ GFI NEC-BSC documentation in the existing HELP system,
- recognize, draw, and edit source and receiver array geometry,
- perform model integrity checks,
- recognize and edit NEC-MOM source/receiver cards (SM, RM),
- improve the text editor to handle large NEC-BSC output files,
- hasten model development by the addition of customized building blocks,
- capability to visually represent the ground plane as colored (shaded) object,
- improvement capability to print model, plots, etc..

Modifications performed on the control line-editor portion of EAM-BSC should be added to provide the following capabilities and features:

- recognition of the GR, PR, and RD following structure-geometry cards,
- functional display of customized dialog boxes for the GR, PR, RD cards,
- functional display of special dialog boxes for the CM, CE, RT, UF, UN, and US cards.

Modifications to the post-processor portion of the EAM-BSC could provide the following capabilities and features:

- improvements to the existing linear-plot format,
- display and hard-copy presentation of near-field data in linear plot format,
- display and hard-copy presentation of far-field data in polar-plot format.

These EAM module improvements would significantly enhance its current capability. The EAM software has been design to provide analysts, designers, and planners with user-friendly GUI access to some of the most accurate antenna performance-prediction software in the world. In this regard, it significantly enhances the capability of these users to perform their tasks with respect to antenna technology. It does not, however, provide complete solutions to the complete radio-link analysis and design problem. For this reason, it is recommended that EAM be integrated into a "larger" Windows-based tool for radio-system performance prediction. In other words, integrate EAM with state-of-the-art radio-link prediction software such as:

- Groundwave (Longley-Rice, Wagner, GW, etc.)
- Troposcatter (TROPO, Longley-Rice, etc.)
- Meteor Burst (METEORLINK, BURST, BLINK, etc.)
- Skywave (MFWORKS, IONCAP, ASAPS, IONORAY, SKYCOM, etc.)
- Satellite Communications (WESCOM, etc.)
- Nuclear Effects (WESCOM, WEPHCOM, WEDCOM, etc.)

In addition, network analysis and design tools - from a propagation and link performance perspective versus network protocol - should also be added.

Finally, EAM is currently restricted to MS Windows-capable PCs. Since many designers and analysts operate in a workstation environment, it is strongly recommended that EAM be "ported" to a suitable workstation. This effort would benefit many users, such as NAIC, who rely on workstations for much of their analysis tasks. Moreover, the execution time of many NEC and BSC models would be significantly reduced from the corresponding PC times. Of course, software developed to integrate EAM with radio-system performance software would also be developed in a workstation version.

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1 INTRODUCTION

1.1. IDENTIFICATION

This document describes the scientific and technology aspects of the Electromagnetic Antenna Modeling (EAM) program which was implemented by the United States Air Force's (USAF) Foreign Aerospace Science and Technology Center (FASTC). This document was developed by Science Applications International Corporation (SAIC) under contract number F306020-91-C-0098 with Rome Laboratory in accordance with the associated Statement of Work (SOW).

1.2. SYSTEM OVERVIEW

The Electromagnetic Antenna Modeling system (EAM) is a self-contained PC-based family of computer programs designed for use in a Microsoft® Windows™ operating environment. EAM was designed to meet FASTC's operational requirements for a flexible antenna modeling system which is easy to use, accurate, fast, realistic and expandable. The EAM software combines the simplicity and speed of closed-form solutions with the accuracy and flexibility of rigorous numerical algorithms to produce a comprehensive antenna modeling and analysis tool. These features aid FASTC in their mission to evaluate foreign antenna technology based on intelligence data.

The EAM system consists of three modules which were developed to analyze and design antennas: EAM-QL, EAM-NEC, and EAM-BSC. The Quick-Look (EAM-QL) module provides quick parametric analysis of twenty traveling wave, standing wave and aperture antennas. The EAM-NEC module is a comprehensive antenna modeling program which includes a three dimensional drawing package, sophisticated plotting routines, and the Numerical Electromagnetic Code (NEC). EAM-NEC is useful for the analysis and design of antennas which are less than a few wavelengths in size. The EAM-BSC module is a comprehensive antenna modeling program for antenna whose dimensions exceed a few wavelengths. It includes a three-dimensional drawing package, post processor and the Basic Scattering Code.

The EAM-QL module is designed for interactive antenna analysis in a rapid turnaround mode. Its fundamental algorithms include closed form

and simple Method of Moments (MoM) solutions for twenty different antennas. Since computationally simple solutions are used, predictions for each antenna can be obtained in seconds. Key antenna performance parameters produced by EAM-QL include peak gain, beamwidth, and input impedance.

The EAM-NEC module was designed to simplify the analysis of more complicated antenna systems by development of a sophiscated graphical user interface which encompasses the Numerical Electromagnetics Code. Inputs are specified through a user-friendly drawing package which serves as a pre-processor for NEC. This useful feature provides the ability to visualize complex antennas in their environments, thus avoiding time-consuming and costly input errors. The NEC post-processing routines include a polar plotting feature to display user-specified radiation patterns. It also includes the ability to visually represent the current intensity on the individual wires that comprise the antenna model. EAM-NEC provides detailed performance parameters such as gain, beamwidth, input impedance, side-lobe levels and depth of nulls for any user-defined antenna structures.

EAM-BSC is similar in design to EAM-NEC in that it consists of a graphical user interface for Ohio State University's Numerical Electromagnetic Code-Basic Scattering Code (NEC-BSC). EAM-BSC was designed to predict scattering from electrically large objects (more than a few wavelengths in size). Some of the key features of EAM-BSC include a 3D model definition window, user-friendly dialog boxes, a NEC-BSC execution interface, and the ability to rapidly display two-dimensional E and H radiation patterns versus angle or frequency in Cartesian format.

The EAM software is a flexible system which is useful for engineers at all levels of sophistication. Engineers who are not familiar with antenna systems can use the Quick-Look module to get a fast and easy initiation into the world of antenna modeling. More experienced engineers can take full advantage of the state-of-the-art modeling techniques used by EAM-NEC and EAM-BSC. These features make EAM a versatile system for antenna modeling and analyzing antenna systems.

1.3. DOCUMENT OVERVIEW

The purpose of this document is to present the major scientific results of the EAM program. This section provides an overview of the EAM system and the content of this document. Section 2 contains a list of all Government and non-Government documents which contributed to the completion of the EAM program. Section 3 describes the Quick-Look

module. Section 4 describes the EAM-NEC Module and Section 5 describes the EAM-BSC. Section 6 discusses validation of the antenna algorithms developed for the Quick-Look Module. Section 7 contains an alphabetical listing of all acronyms, abbreviations and their definition as used in this document.

2 REFERENCE DOCUMENTS

2.1. GOVERNMENT DOCUMENTS

The following Government documents contributed to the successful completion of the EAM program.

2.1.1. SPECIFICATIONS

None.

2.1.2. STANDARDS

DI-MISC-80771/T	Data Item Description: Scientific and Technical Reports (Final)
DOD-STD-2167A	Defense System Software Development 29 February 1988 - Sections 4.2.1, 4.2.2, 4.2.7, 4.2.10, 4.5.4,4.6.4C, 5.1.3, 5.3.2.1, and Appendix B
MIL-STD-490	Specification Practices
PR I-1-4022	Statement of Work for Electromagnetic Antenna Modeling, 20 December 1990
F306020-91-C-0098	Contact Award for Electromagnetic Antenna Modeling, 18 July 1991
F306020-91-C-0098	Contact Modification for Electromagnetic Antenna Modeling, 31 October 1991
F306020-91-C-0098	Contact Modification for Electromagnetic Antenna Modeling, 14 January 1994

2.1.3. DRAWINGS

None.

2.1.4. OTHER PUBLICATIONS

W-7405-Eng-48	Numerical Electromagnetics Code (NEC) January 1981 Part I Program Description - Theory
W-7405-Eng-48	Numerical Electromagnetics Code (NEC) January 1981 Part II Program Description - Code
W-7405-Eng-48	Numerical Electromagnetics Code (NEC) January 1981 Part III Method of Moments, User's Guide
716199-13	Near Zone - Basic Scattering Code User's Manual with Space Station Applications March 1989

Copies of specifications, standards, drawings, and publications required by suppliers in connection with specified procurement functions should be obtained from the contracting agency or as directed by the contracting officer.

2.2. NON-GOVERNMENT DOCUMENTS

The following non-Government documents contributed to the successful completion of the EAM program.

2.2.1. SPECIFICATIONS

None.

2.2.2. STANDARDS

Software Requirments Specification
2 March 1993

Software Users Manuals
EAM-QL 29 June 1993
EAM-NEC 1 September 1993
EAM-BSC 7 September 1993

Software Test Plan
4 June 1993

2.2.3. DRAWINGS

None

2.2.4. OTHER PUBLICATIONS

Borland's Turbo Pascal® for Windows 1.0

Microsoft® Windows™ 3.0 User's Guide

Microsoft® Windows™ 3.0 Software Development Kit

Microsoft® Word for Windows™ version 2.0

3 QUICK-LOOK MODULE (EAM-QL)

The Quick-Look module combines a user-friendly graphical user interface (GUI) with analysis software to predict the performance of twenty antenna types. The GUI allows quick specification of the antenna's physical description. The EAM-QL module was specifically designed for interactive antenna analysis in a rapid turnaround mode. It's run times vary from instantaneous to 39 seconds on a 80486-based PC running at 33 MHz (Figure 3-1).

These antennas represent the typical antennas that FASTC would analyze. The method of solution depends on the particular antenna type under study. Some of the antennas are simple enough that accurate closed-form solutions are available. Others required simplifying assumptions to produce tractable closed-form solutions. For the remainder, no closed-form solution exists and numerical techniques are employed.

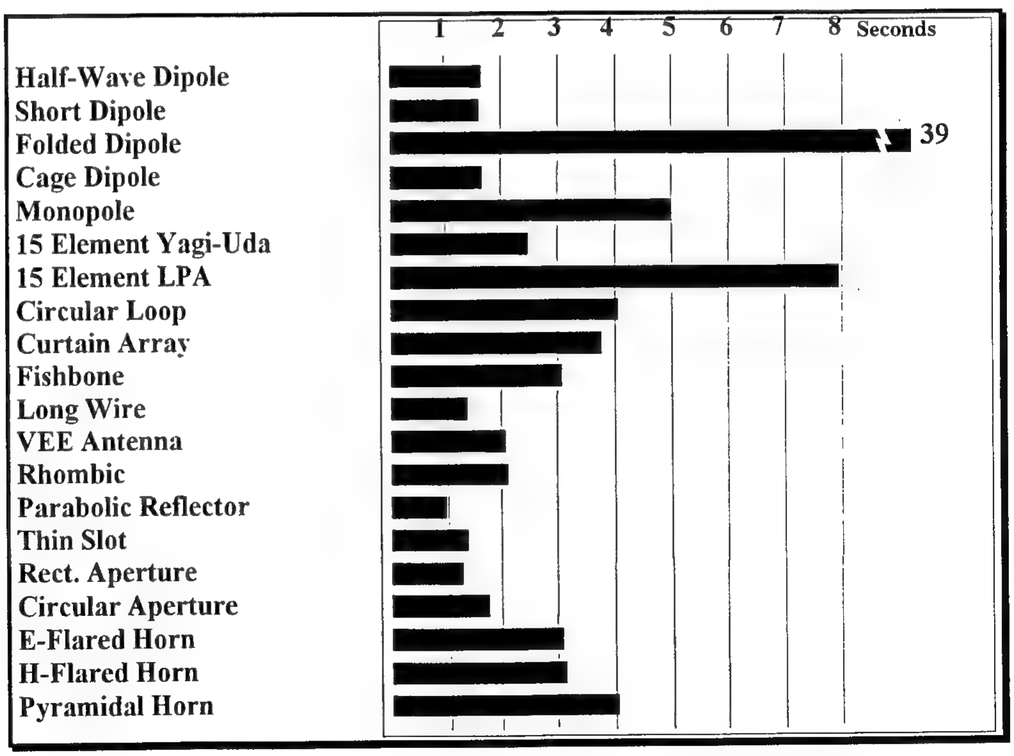

Figure 3-1 Computational Time on a 486-33 MHz PC
Quick-Look Antenna Modules

Each antenna type within the Quick-Look module has its own antenna window which contains four sub-windows used for input and output. The input window is tailored to each antenna type to allow the user to describe the physical characteristiccs of the antenna. An antenna image is displayed to the right of the input window. This image is provided as a reference for all of the required physical input parameters, e.g., length, radius, height. Outputs of the analysis are displayed in two output windows. A text-based output window displays calculated parameters such as maximum gain, half power beamwidth, radiation resistance, etc. In addition, it re-displays the input parameters as used in the analysis. The radiation pattern window contains calculated pattern data for any user-specified plane of view.

The Quick-Look module's GUI also uses Windows™ Multiple Document Interface (MDI) capability to allow several windows to be visible simultaneously. This feature allows performance comparisons to be made for different antenna types or for variations of the same antenna type. In addition, a detailed context sensitive help system and custom menu items such as "Tile Patterns", "Bring Window to Top", and "Select Defaults" simplify operation and enhance utility.

3.1 THE QUICK-LOOK ANTENNA WINDOW

The Quick-Look "Antenna Window" is the foundation for each antenna module's GUI. Slightly modified for each antenna module, its main purpose is to act as the hub for all data required for and resulting from an antenna analysis, thus relieving the user from having to search elsewhere for data.

Each of the antenna windows were designed to provide a consistent layout of the inputs, outputs, and antenna image. They were also designed to clearly specify all the pertinent input and output parameters of the specified antenna. These two design objectives provide a means that the user's interface for each particlur antenna type will be consistance; inputs and outputs are easlily reconginizable, and all formats are displayed in a similar fashion.

Each antenna module, i.e. Dipole, Rhombic, Yagi, etc., is represented by its own antenna window. The window is titled to indicate the antenna type, or in the case of a saved analysis, the file and path name. As shown in Figure 3-2, it is comprised of four sub-windows, or child windows, which include an input text window, an antenna image window, output text window, and a gain pattern window. All data is exchanged from within these child windows. The child windows can be moved, re-sized, and overlapped using conventional Windows

manipulation techniques, however, since they are child windows, they always remain within the confines of the antenna window.

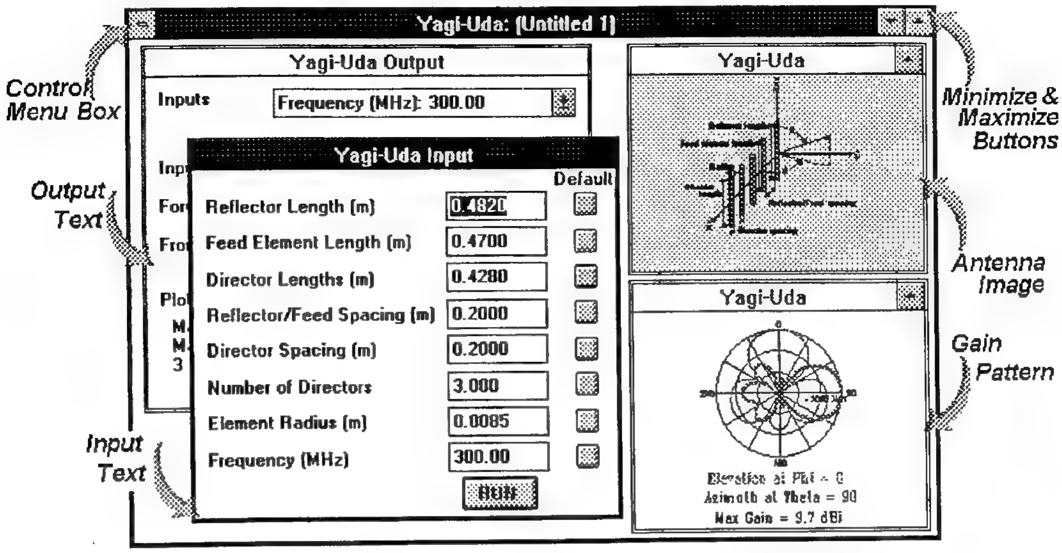

Figure 3-2. Typical Layout of a Quick-Look Antenna Window

Quick-Look gives you the additional capability of opening multiple antenna windows simultaneously. This provides you with the ability to compare the results of multiple analyses of different antennas, or of the same antenna with varied inputs, i.e. a parametric study. An example of a parametric study is provided in Figure 3-3 where a rhombic antenna has been modeled with arm lengths of 1, 2, 3, and 4 wavelengths, as indicated by the titles. The resulting radiation patterns are quickly compared by displaying them simultaneously through the use of the Window|Tile|Tile Patterns menu item.

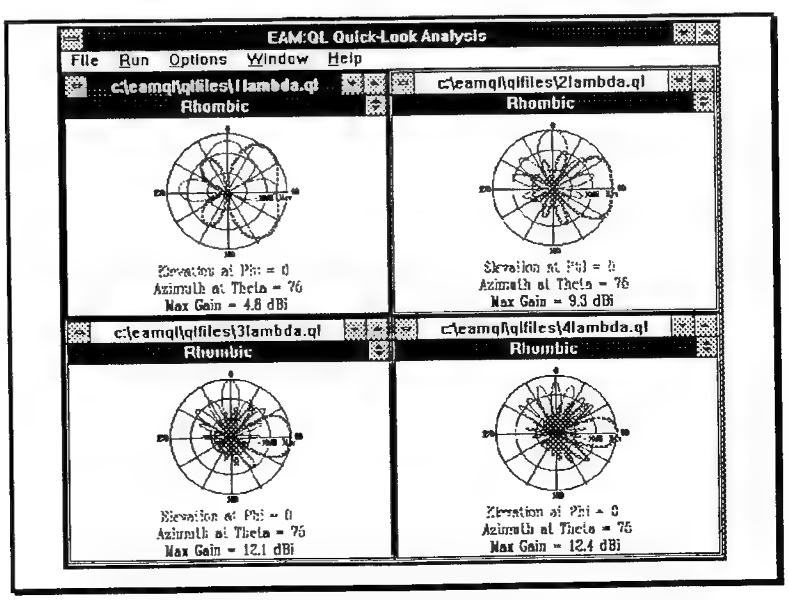

Figure 3-3. An Example of a Parametric Study of 4 Rhombic Antennas

3.1.1 Input Text Window

The input text window allows specification of the inputs required for the selected antenna. Because the physical and electromagnetic characteristics vary from antenna to antenna, the parameters listed in the input windows will also vary. Entering input parameters is a simple procedure which involves clicking on the desired input box and typing in a value. To run an analysis, you can press "ENTER", click on the "RUN" button, or select the Run menu item. If an invalid value is entered as an input, an error message is displayed when the you attempt to execute the antenna analysis. An alternative to typing a value is to click on the "default" button. This will cause a typical default input value to be displayed for the particular parameter.

3.1.2 Antenna Image Window

An illustration of the antenna is provided in a graphics window to display the physical characteristics of the structure. It includes a graphical representation of many of the dimensional inputs required for execution of the model. These dimensional inputs correspond to values you must enter in the input text window. The Antenna Image window also includes a display of the X, Y, and Z coordinate axes to illustrate the orientation of the antenna with respect to the radiation pattern plots. To view the image at a different magnification, you can stretch the window any way you like. It should be noted that the image is only an example of the antenna type. Its characteristics do not change as user-inputs are changed, so the relative sizes, positions, and quantities of elements may not exactly represent the antenna under study.

3.1.3 Radiation Pattern Window

The radiation pattern window is an output window that provides azimuth (blue) and elevation (red) cuts of the antenna's 3 dimensional power gain pattern. These pattern cuts can be represented on either polar or linear plots through the use of the Options|Pattern Type menu item. Most of the Quick-Look antenna modules allow you to specify the azimuth and elevation pattern cuts which will be displayed in this window.

The Quick-Look antenna modules usually orient the antenna to provide boresite along the X-axis ($\phi=0°$). The orientation of the antenna with respect to the radiation pattern plots can be determined

by viewing the coordinate axes illustrated in the Antenna Image window described in Section 3.1.2.

In Quick-Look, both azimuth and elevation patterns can be displayed on the same plot. This may cause some confusion if compared directly with many of the manufacturer's gain plots. Generally, most manufacturers align the elevation and azimuth main beams together on the same plot, but, because of this alignment, they do not supply any angle labels . In Quick-Look, the plots are labeled with the angle representing the pattern cuts displayed. As a result both pattern cuts sweep through 360 degree and share the same labels. The difference is that for an elevation cut $\theta=0°$ represents the Z-axis and for an azimuthal cut $\phi=0°$, represent the X-axis.

The polar radiation patterns are normalized to the maximum calculated gain of the azimuth and elevation patterns chosen. Each subsequent inner circle represents a gain reduction of 10 dB. For linear plots, the maximum Y-axis value corresponds to the maximum calculated gain. Each lower horizontal line represents a gain reduction of 10 dB.

3.1.4 Output Text Window

The Output Text window provides a display of inputs as they are used in the algorithm, antenna specific output data, and radiation pattern characteristics. To reduce screen clutter, inputs are stored in a drop-down list box and are not completely visible until their display is requested by the user. Display of the inputs is accomplished by clicking mouse on the down-arrow at the right side of the list box. The down-arrow of the listbox can be seen in the Output Text window shown in Figure 3-2. The remaining parameters are always in view when the Output Text window is displayed. Please note that it is not possible to manually change any of the values displayed in this window, this includes the inputs.

Because not all antennas have the same physical and electromagnetic characteristics, the output parameters listed in this window will vary from antenna to antenna. A more detailed discussion of outputs specific to individual antennas can be found in Section 3.2.

In addition to the antenna specific parameters mentioned above, all the Output Text windows provide characteristics of the calculated radiation pattern plot shown in the Radiation Pattern window. These characteristics include the peak gain, 3 dB beamwidths, and maximum gain pointing angle for the azimuth and elevation patterns. Care should be taken in interpreting these results because they are only indicative of the calculated radiation pattern cuts and not the overall

pattern of the antenna. This statement implies that the antenna's peak gain might be greater than the value represented here if the calculation was not performed at the appropriate angles. Since most of the Quick-Look antennas are oriented to provide peak gain down the X axis, specifying $\phi=0°$ for the elevation pattern cut will usually ensure inclusion of the peak gain in the calculation.

3.2 THE QUICK-LOOK ANTENNA MODULES

EAM-QL, or Quick-Look, includes the capability to analyze the performance of 20 different types of antennas. This large selection of antennas covers the entire RF spectrum, thus providing the capability to design and analyze antennas for a wide variety of applications. These applications include a diverse set of communications systems which range from ELF submarine communication systems to SHF satellite applications.

The antenna modules included in Quick-Look were modeled by using a wide variety of techniques. Some of the antenna systems are simple enough that accurate, closed-form solutions are readily available. Others required simplifying assumptions to produce tractable closed-form solutions. For the remainder, no closed-form solutions exist and moment method techniques were employed. A description of the techniques used to analyze each of the individual antenna modules is provided in the subsections that follow. These descriptions provide a high level understanding of the algorithms employed. The underlying assumptions of each antenna module are also given.

Note: Even though extensive error checking has been incorporated in each antenna module to help you avoid violating solution assumptions, you are cautioned to read these subsections carefully.

3.2.1 The Array Module

The array module uses the standard array factor approach to compute the radiation pattern of a uniform array of identical radiators[1]. In this approach, the radiated field from a single antenna is multiplied by the array factor. The array factor is an interference pattern that depends only on the relative spacing and phasing of the elements in the array and not on the pattern of the individual radiators. The array module computes the array factor and multiplies it by the radiation pattern of a previously computed Quick-Look antenna. This point by point multiplication of radiation patterns can be stated mathematically as:

$$E_{total}(\theta,\phi) = E_{single\ element}(\theta,\phi) \times \text{Array Factor}(\theta,\phi)$$

Where the array factor term can be found in [3] as:

$$Array\_Factor(\theta,\phi) = \frac{1}{N_x N_y N_z} \frac{Sin\left(\frac{N_x}{2}\Psi_x\right)}{Sin\left(\frac{\Psi_x}{2}\right)} \frac{Sin\left(\frac{N_y}{2}\Psi_y\right)}{Sin\left(\frac{\Psi_y}{2}\right)} \frac{Sin\left(\frac{N_z}{2}\Psi_z\right)}{\mathrm{Sin}\left(\frac{\Psi_z}{2}\right)}$$

$$\Psi_x = kd_x \sin(\theta)\cos(\phi) + \beta_x$$
$$\Psi_y = kd_y \sin(\theta)\sin(\phi) + \beta_y$$
$$\Psi_z = kd_z \cos(\theta) + \beta_z$$

where:

k = wave number ($2\pi/\lambda$).

$N_{x,y,z}$ = number of elements in x, y, and z directions.

$d_{x,y,z}$ = distance between adjacent elements in x, y, and z.

$\beta_{x,y,z}$ = phase difference between adjacent elements in x, y, and z.

The array module has two modes of operation. In one mode, the pattern multiplication is performed as described above. In the second mode, point sources are assumed so no pattern multiplication is required. In this second approach, the radiation pattern produced by the array factor term is plotted alone.

[1] C. A. Balanis, Antenna Theory: Analysis and Design, New York: Harper and Row, 1982, Chapter 6.

The array factor approach assumes no interaction between elements in the array. This assumption is valid for element spacing greater than about one wavelength. For element spacing less than one wavelength the model may provide erroneous results. The degree of the error will depend upon the type of antenna under consideration. Consider two half wavelength dipole antennas arranged collinearly as illustrated in Figure 3.2-1a. Although the separation between the antenna's phase center is less than one wavelength, there will be little interaction between the dipoles. This lack of interaction results from the fact that the individual dipole antennas have deep nulls off their ends. Since these nulls are in the direction of the adjacent antenna, the two dipoles act independently and the array factor assumption is valid. In Figure 3.2-1b, on the other hand, the parallel dipoles interact because they are positioned directly in line with the main beam of the adjacent antenna. In this case, the array factor is still correct, but the individual dipole pattern is incorrect due to the interaction of the second dipole. To analyze the performance of the antennas in Figure 3.2-1b a more rigorous approach like that used by EAM-NEC should be employed.

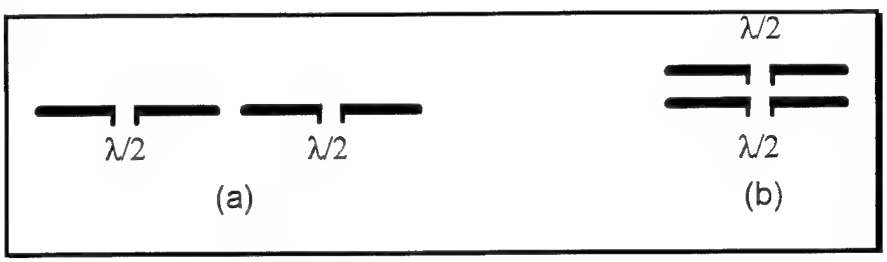

Figure 3.2-1 a) Collinear Dipoles and b) Parallel Dipoles

The array module antenna window is shown in Figure 3.2-2. As displayed, its inputs are configured to model an array of point sources.

A additional feature of the array module is that it can also be used to introduce ground effects into a previous Quick-Look run. To take advantage of this feature run a Quick-Look module in free space and save the file. Use this file as the input file to the array module, specifying the desired height above ground and 1 element in the X, Y, and Z directions.

Note: Care should be taken to ensure that the effects of the ground are not introduced twice. This situation could result if the previous Quick-Look run already included the effects of the ground. In these cases, be sure to avoid the use of ground effects by specifying an antenna height of 0 meters in the array module.

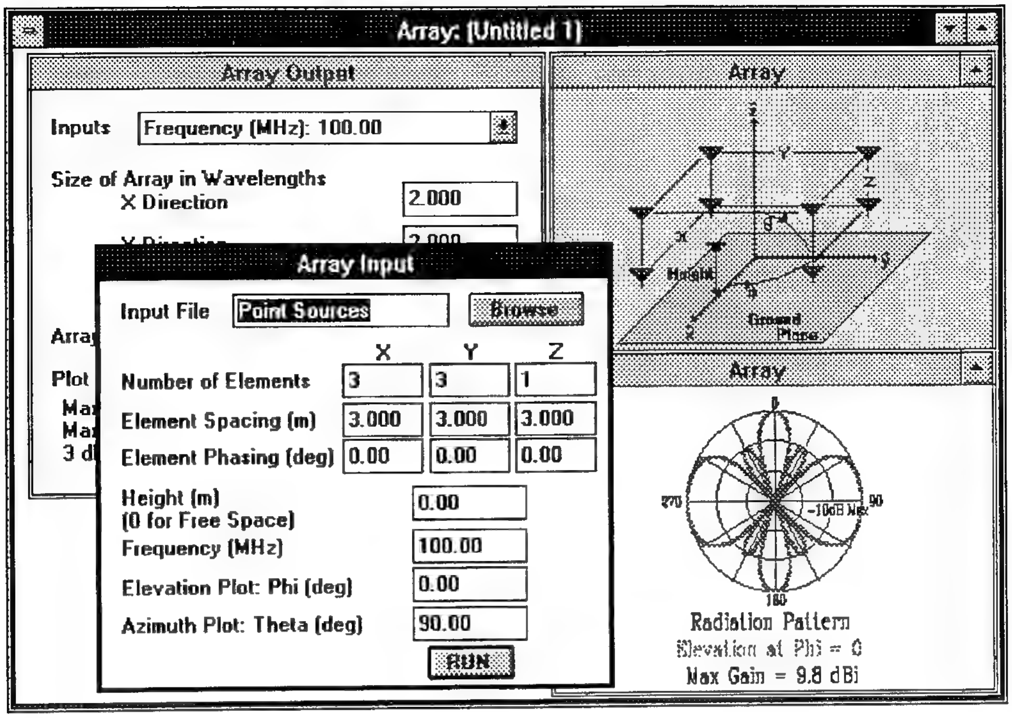

Figure 3.2-2. Array Module Antenna Window.

3.2.1.1 Input Parameters

Input File Name

This input will contain either the word *Point Sources* for analysis of a constant gain antenna, or the name of a file which contains the results of a previous Quick-Look analysis.

Number of Elements

The radiators are oriented to form a grid with the user specifying: the number of elements in each direction, their relative spacing, and their relative phasing. This input represents the number of elements in the X, Y, and Z directions.

Element Spacing (m)

Specify the distance in meters between elements in the X, Y, and Z directions. If there is only one element in a particular direction, this input will be ignored.

Element Phasing (deg)

This input represents the phase lead or lag between adjacent elements. If, for example, there are three elements in the X direction and we specify a 90 degree phase difference, the first element will be driven with a phase of 0 deg, the second at +90 deg, and the third at +180 deg.

Height (m)

This represents the height of the array above a perfect ground. The height is measured from the center of the array and therefore must be large enough to have the array completely above the ground. Entering a value of zero will assume that no ground plane is present and the array is in free space. You should use 0 for the height (free space) if the input antenna file already includes the effects of the ground.

Frequency (MHz)

This is the frequency at which the array will be analyzed. When using a previous Quick-Look analysis, the radiation pattern is multiplied by the array factor computed by this module, therefore, *Frequency* must be the same in both modules. If the array *Frequency* input differs from original analysis, the array *Frequency* will be modified automatically.

Elevation Plot: Phi (deg) \ Azimuth Plot: Theta (deg)

Theta and Phi are the angles which define the elevation and azimuth cuts computed by the Quick-Look module. In some Quick-Look modules these values are not user-defined inputs. For these modules, the pattern is usually computed in the XY (theta = 90 degrees) and XZ (phi = 0 degrees) planes. As with the *Frequency* input, these inputs must match the original analysis inputs.

3.2.1.2 Output Parameters

Size of Array (Wavelengths)

The size, in wavelengths, of the array in the X, Y and Z directions is computed from the frequency, the number of elements, and the spacing between elements. This can be represented mathematically as:

$$L = \frac{(N-1) \times S \times F}{300}$$

where

L = Length (wavelengths)

N = Number of Elements

S = Spacing (m)

F = Frequency (MHz)

Height (Wavelengths)

This output is the height of the array's center above the ground (measured in wavelengths). It depends only on the height (in meters) and the operating frequency.

3.2.2 Cage Dipole

A cage dipole is a variation of a conventional dipole where the diameter of the radiating element has effectively been increased to broaden the bandwidth of the antenna. Increasing the diameter of an antenna is a commonly used technique for increasing its bandwidth. Because very fat antenna elements are cumbersome, the increase in diameter is often achieved by using several parallel dipole elements arranged to form a circle of the desired diameter. This configuration results in an accurate simulation of the axial currents that would be present on a single fat dipole of similar radius. The antenna is driven by connecting the elements at their center to form a single feed point.

Separate approaches are used to model impedance and radiation pattern of the cage dipole antenna. The driving-point impedance is computed from its self-impedance and the mutual impedance between that dipole and every other dipole. Connecting the individual dipole elements in parallel at the feed point yields the driving-point impedance of the overall antenna. The self impedance can be found in Reference [2] as:

$$R_{self} = \frac{\eta}{2\pi}\left\{\begin{aligned} & C + \ln(kl) - C_i(kl) + \frac{1}{2}\sin(kl)\left[S_i(2kl) - 2S_i(kl)\right] \\ & + \frac{1}{2}\cos(kl)\left[C + \ln\left(\frac{kl}{2}\right) + C_i(2kl) - 2C_i(kl)\right] \end{aligned}\right\}$$

$$X_{self} = \frac{\eta}{4\pi}\left\{\begin{aligned} & 2S_i(kl) + \cos(kl)\left[2S_i(kl) - S_i(2kl)\right] \\ & -\sin(kl)\left[2C_i(kl) - C_i(2kl) - C_i\left(\frac{2ka^2}{l}\right)\right] \end{aligned}\right\}$$

where

$$C_i(x) = -\int_x^{\infty} \frac{\cos(x)}{\tau} d\tau \,, \qquad S_i(x) = \int_0^{x} \frac{\sin(x)}{\tau} d\tau \,,$$

C = 0.5772 is Euler's constant,

a = the element radius,

l = the element's length.

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[2] C. A. Balanis, Antenna Theory: Analysis and Design, New York: Harper and Row, 1982, . pp. 124, 294, 744.

The mutual impedance is presented in Kraus[3] as:

$$R_{mutual} = \frac{30}{\sin^2\left(\frac{kl}{2}\right)} \left\{ \begin{array}{l} 2\left(2+\cos(kl)\right) C_i(kd) \\ -4\cos^2\left(\frac{kl}{2}\right)\left[C_i\left(\frac{k}{2}\left(\sqrt{4d^2+l^2}-l\right)\right)+C_i\left(\frac{k}{2}\left(\sqrt{4d^2+l^2}+l\right)\right)\right] \\ +\cos(kl)\left[C_i\left(k\left(\sqrt{d^2+l^2}-l\right)\right)+C_i\left(k\left(\sqrt{d^2+l^2}+l\right)\right)\right] \\ +\sin(kl)\left[\begin{array}{l} S_i\left(k\left(\sqrt{d^2+l^2}+l\right)\right)-S_i\left(k\left(\sqrt{d^2+l^2}-l\right)\right) \\ -2S_i\left(\frac{k}{2}\left(\sqrt{4d^2+l^2}+l\right)\right)+2S_i\left(\frac{k}{2}\left(\sqrt{4d^2+l^2}-l\right)\right) \end{array}\right] \end{array} \right\}$$

$$X_{mutual} = \frac{30}{\sin^2\left(\frac{kl}{2}\right)} \left\{ \begin{array}{l} -2\left(2+\cos(kl)\right) S_i(kd) \\ +4\cos^2\left(\frac{kl}{2}\right)\left[S_i\left(\frac{k}{2}\left(\sqrt{4d^2+l^2}-l\right)\right)+S_i\left(\frac{k}{2}\left(\sqrt{4d^2+l^2}+l\right)\right)\right] \\ -\cos(kl)\left[S_i\left(k\left(\sqrt{d^2+l^2}-l\right)\right)+S_i\left(k\left(\sqrt{d^2+l^2}+l\right)\right)\right] \\ +\sin(kl)\left[\begin{array}{l} C_i\left(k\left(\sqrt{d^2+l^2}+l\right)\right)-C_i\left(k\left(\sqrt{d^2+l^2}-l\right)\right) \\ -2C_i\left(\frac{k}{2}\left(\sqrt{4d^2+l^2}+l\right)\right)+2C_i\left(\frac{k}{2}\left(\sqrt{4d^2+l^2}-l\right)\right) \end{array}\right] \end{array} \right\}$$

where d is the distance between the elements in question and l is their length.

The equations given by Balanis and Kraus have singularities when the cage dipole's length is an integral number of wavelengths ($l=n\lambda$). The singularity is cause by the assumption of a sinusoidal current distribution which results in a zero feed-point current and thus infinite feed-point impedance. In reality, the current is small, but non-zero. The singularities were avoided by never letting *Sin(kl)* go below 10^{-5}.

The radiation pattern of the cage dipole is practically identical to that of a single dipole of equal length. A sine wave current distribution is assumed in the computation of this radiation pattern. The gain equation is derived

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[3] J. D. Kraus, Antennas, Second Edition, New York: McGraw-Hill, 1988, pp. 426-427.

from the electric field equation[4] and modified for rotation of the element orientation into the XY plane. The gain equation is expressed as:

$$G(\theta,\phi)=\frac{120}{R_{self}}\left[\frac{\cos\left(\frac{kl}{2}\sin\theta\sin\phi\right)-\cos\left(\frac{kl}{2}\right)}{\sqrt{1-(\sin\theta\sin\phi)^2}}\right]^2$$

Where R_{self} is the radiation resistance of a dipole of length l.

The Cage Dipole antenna window is shown in Figure 3.2-3. Brief descriptions of the input and output parameters required for the cage dipole analysis are listed in the following subsections.

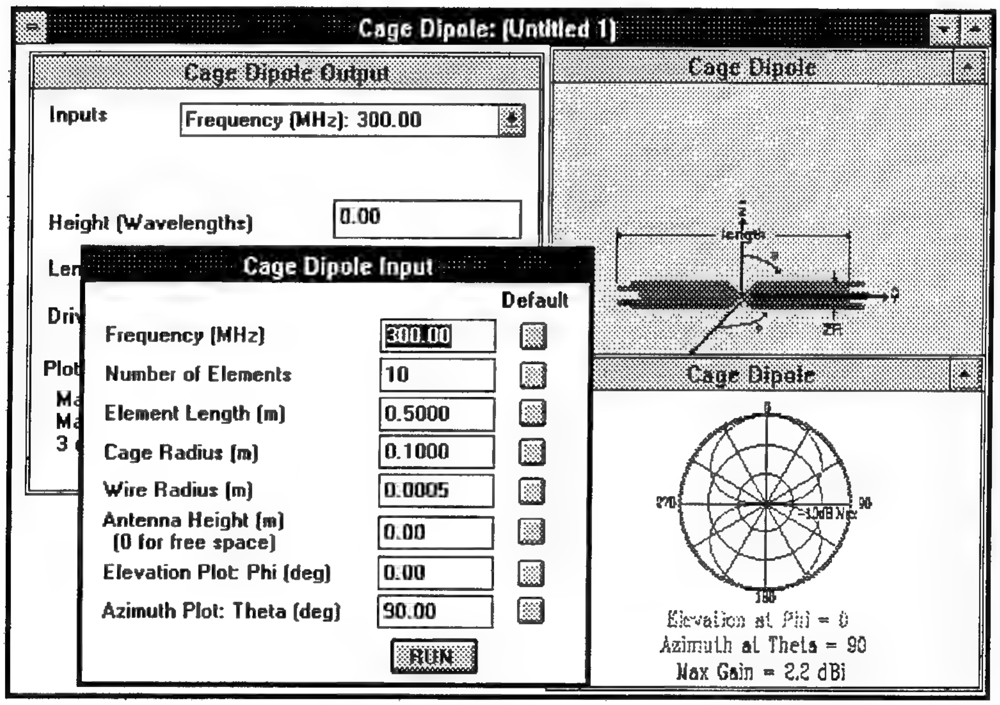

Figure 3.2-3. Cage Dipole Antenna Window.

3.2.2.1 Input Parameters

Number of Elements

This input represents the number of thin wire elements that comprise the cage dipole antenna.

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[4] C. A. Balanis, Antenna Theory: Analysis and Design, New York: Harper and Row, 1982, pg. 120.

Element Length (m)

This input represents the length of the thin wire elements that make up the cage dipole.

Cage Radius (m)

The cage dipole antenna is modeled as a number of parallel thin wire elements oriented to form a cylinder. This input represents the radius of this cylinder.

Wire Radius (m)

This input is the radius of the individual thin wire elements that comprise the cage dipole.

Antenna Height (m)

This input represents the height of the cage dipole above a perfect ground. Entering a value of zero will assume that no ground plane is present and the cage dipole is in free space.

3.2.2.2 Output Parameters

Antenna Height (Wavelengths)

This output is the height of the cage dipole above the ground (measured in wavelengths). It depends only on the height (in meters) and the operating frequency.

Element Length (Wavelengths)

This output represents the length of the cage dipole when measured in wavelengths. The antenna will be close to resonant when the cage length is about 1/2 wavelength long.

Driving-Point Impedance (Ohms)

This output represents the driving-point impedance measured at the input terminals of the cage dipole. The approach used to model this antenna assumed a sinusoidal current distribution on each of the elements that comprise the cage dipole. For elements with lengths nearly one wavelength (or multiples thereof), this assumption results in negligible current and thus infinite impedance at the input terminals. Experimental evidence has shown that the impedance is finite and the sinusoidal approximation fails for elements near one wavelength long.

3.2.3 Circular Aperture

This aperture antenna consists of a circular hole cut into a perfectly-conducting, infinite metal plate. Circular apertures are typically used at microwave frequencies for conformal antenna designs. One interesting feature of the these antennas is that their radiation pattern is identical to that of a uniformly-illuminated paraboloid of equal diameter. Like rectangular apertures, circular apertures can be excited in a number of different ways.

The excitation method affects the electromagnetic field distribution over the surface of the aperture which in turn affects the overall radiation pattern of the antenna. The Quick-Look module includes two of the most useful excitation modes; uniform and TE_{11}. In the uniform excitation mode, the electric field along the surface of the aperture is constant in both principal planes (i.e., E and H). In the TE_{11} mode, a more complicated transverse electric field is present across the aperture.

The equivalence principle [5] is used to analyze the performance of this and all aperture antennas included in the Quick-Look program. In this technique, the actual antenna source is replaced by an equivalent source that produces the same EM fields in a given region. For a circular aperture of radius a, this approach results in a:

$$E_\theta = j\frac{ka^2E_0e^{-jkr}}{r}\left\{\sin\phi\frac{J_1(ka\sin\theta)}{ka\sin\theta}\right\}$$

$$E_\phi = j\frac{ka^2E_0e^{-jkr}}{r}\left\{\cos\theta\cos\phi\frac{J_1(ka\sin\theta)}{ka\sin\theta}\right\}$$

$$P = C\left\{(\sin\phi\,J1\,)^2 + (\cos\theta\cos\phi\,J2)^2\right\}$$

Where P is the absolute value of the time averaged Poynting vector.

If the aperture is excited with a uniform distribution, then:

$$C = \frac{\pi a^4E_0^2}{60\lambda^2r^2}$$

$$J1 = J2 = \frac{J_1(ka\sin\theta)}{ka\sin\theta}$$

If the excitation mode is TE_{11}, then:

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[5] C. A. Balanis, Antenna Theory: Analysis and Design, New York: Harper and Row, 1982, pp. 478-487.

$$C = \frac{\pi a^4 E_0^2 (J1(1.841))^2}{60\lambda^2 r^2}$$

$$J1 = \frac{J_1(\mathrm{ka}\sin\theta)}{ka\sin\theta}$$

$$J2 = \frac{J_0(ka\sin\theta) - J_1(ka\sin\theta)/(ka\sin\theta)}{1-(ka\sin\theta/1.841)^2}$$

where J_0 and J_1 are Bessel functions.

The Circular Aperture antenna window is shown in Figure 3.2-4. Brief descriptions of the input and output parameters required for the circular aperture analysis are listed in the following subsections.

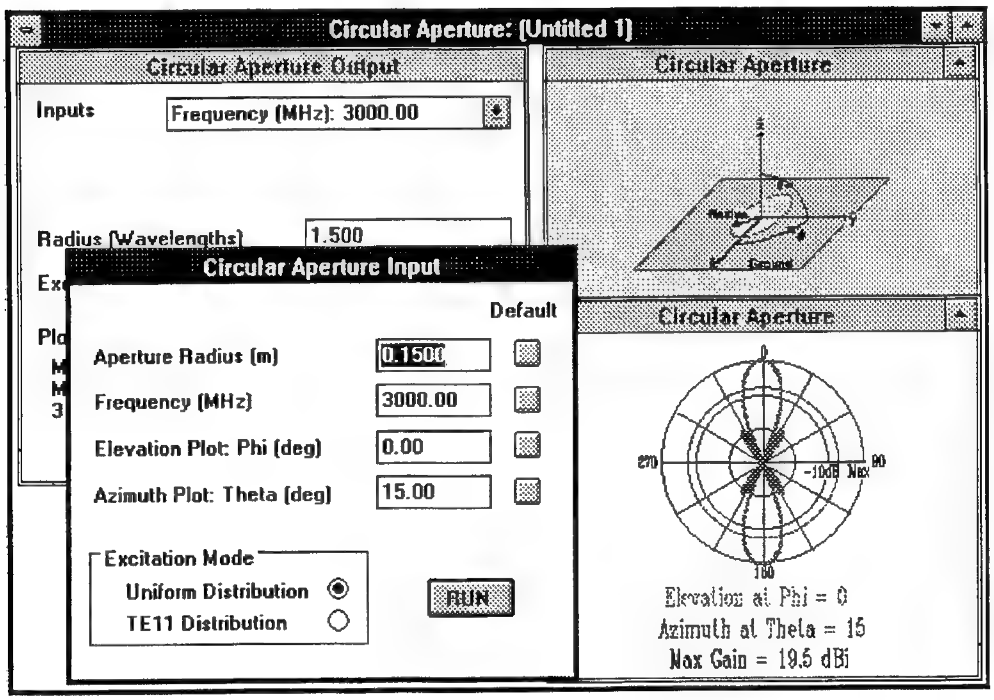

Figure 3.2-4. Circular Aperture Antenna Window.

3.2.3.1 Input Parameters

Radius (m)

This input is the radius of the circular aperture. Refer to the diagram of the circular aperture antenna for a more thorough understanding of this parameter, see Figure 3.2-4.

Excitation Mode - Uniform Distribution

In the Uniform Distribution excitation mode, the electromagnetic field is constant across the entire aperture. Although this distribution is physically unrealizable (it violates boundary conditions), it is a useful analysis tool which can provide insight into the performance of more complex antennas. For example, the radiation pattern of a uniformly-illuminated paraboloid is identical to that of a circular aperture of the same diameter which is excited with a uniform distribution.

Excitation Mode - TE_{11} Distribution

The TE_{11} Distribution mode is the fundamental excitation mode of a circular aperture. It is similar to the uniform distribution, except the electric fields bend at the edges to satisfy the boundary conditions.

3.2.3.2 Output Parameters

Radius (Wavelengths)

This output is the radius of the aperture in wavelengths.

Circular Aperture Output: Excitation Mode

This output allows you to view which excitation mode was used for the calculations. The two options are uniform distribution and TE_{11}.

3.2.4 Curtain Array

The curtain array consists of a number of half-wavelength dipoles oriented parallel to the Y-Axis and in the YZ plane. The elements are fed in phase to produce a directional radiation pattern whose main beam points along the positive X-axis. The gain is further enhanced by a perfectly-conducting, infinite screen positioned behind the array.

The curtain array is modeled using the standard array factor approach for a two dimensional array of dipoles. This array factor technique was described in Section 3.2.1. The dipoles are modeled by assuming a sinusoidal current distribution along their length and integrating this distribution to obtain the radiation pattern. The screen and ground plane are included using the method of images which results in the inclusion of a single term for each reflection.

Both the ground plane and the screen are assumed to be perfectly conducting and infinite in extent. Assuming the ground plane is perfectly conducting is a reasonably good approximation because the antenna produces a horizontally-polarized electric field. One result of the perfectly conducting assumption is that all the energy is reflected into the first quadrant. Because the screen and ground plane are perfect reflectors, no energy is present below or behind the array.

The Curtain Array Antenna Window is shown in Figure 3.2-5. Brief descriptions of the input and output parameters required for the curtain array analysis are listed in the following subsections.

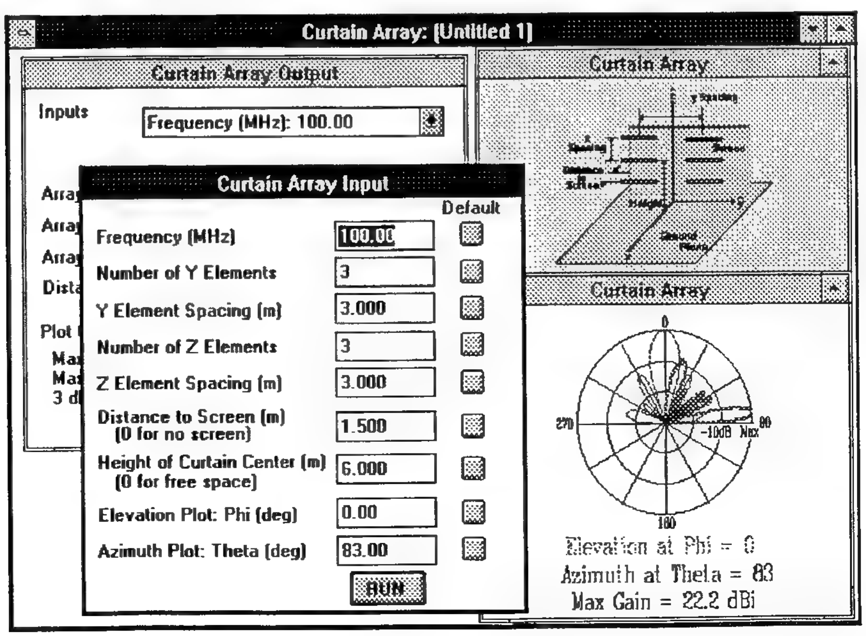

Figure 3.2-5. Curtain Array Antenna Window.

3.2.4.1 Input Parameters

Number of Elements in the Y-Direction

The curtain array consists of a planar array of half wavelength dipoles oriented in the YZ plane. This input is the number of dipoles in the Y-direction.

Spacing Between Elements in the Y-Direction (m)

This input is the spacing between elements in the Y-direction. Refer to the diagram of the antenna for a more thorough understanding of this parameter.

Number of Elements in the Z-Direction

The curtain array consists of a planar array of half wavelength dipoles oriented in the YZ plane. This input is the number of dipoles in the Z-direction, where the Z-direction is perpendicular to the earth's surface.

Spacing Between Elements in the Z-Direction (m)

This input is the spacing between elements in the Z-direction. Refer to the diagram of the antenna for a more thorough understanding of this parameter.

Distance to Screen (m)

The curtain array consists of a planar array of dipoles configured in the YZ plane. Behind this array and parallel to it (i.e. parallel to the YZ plane) is a perfectly reflecting screen. This input is the distance between the planar array of dipoles and the reflecting screen. Since both planes are parallel to the YZ plane, this input is measured along the X-axis. If zero is used for this input no screen is present.

Height of Curtain's Center (m)

This input is the height of the curtain above ground. The height is measured from the center of the curtain and therefore must be large enough to have the curtain completely above the ground. Entering a value of zero will assume that no ground plane is present and the antenna is in free space.

3.2.4.2 Output Parameters

Array Length (Wavelengths)

This output is the size in wavelengths of the curtain array in the Y-direction. It depends only on the number of elements in the Y-direction, their relative spacing, and the operating frequency.

Array Width (Wavelengths)

This output is the size in wavelengths of the curtain array in the Z direction. It depends only on the number of elements in the Z-direction, their relative spacing, and the operating frequency.

Array Height (Wavelengths)

This output is the height in wavelengths of the curtain's center above the ground. It depends only on the height in meters and the operating frequency.

Distance to Screen (Wavelengths)

This output is the distance from the antenna elements to the reflecting screen as measured in wavelengths. It depends only on the screen distance (measured in meters) and the operating frequency.

3.2.5 Dipole

A dipole antenna consists of a single thin wire (typically 1/2 wavelength long) that is fed at its center by a balanced transmission line. The electrical energy travels down the length of the wire and is completely reflected at the wire's end due to the open circuit. This situation results in a standing wave current distribution along the dipole's length. This pattern contrasts the traveling wave pattern produced by antennas like the long wire, rhombic, and VEE.

The approach chosen to analyze the performance of the dipole antenna calculates the electrical current distribution along the dipole's length. This approach employs the method of moments to solve Pocklington's integral equation for the current distribution. Although the method of moments is a rather complicated numerical technique, it is capable of accurate predictions of the current distribution on wire elements of any length. This distribution is then used as the basis for calculating the impedance and radiation pattern results.

The driving-point impedance is determined from the current and voltage at the feed point. The method of moments algorithm used in this module requires an odd number of segments. For each dipole solution, the antenna is sectioned into 3 to 15 segments, depending on the length and frequency. At the center segment, the current is divided into 1 volt to calculate the driving point impedance. This impedance is then combined with the load impedance for the input impedance. The radiation pattern is determined by integrating the current distribution over the wire's length.

The Dipole Antenna Window is shown in Figure 3.2-6. Brief descriptions of the input and output parameters required for the Dipole antenna analysis are listed in the following subsections.

3.2.5.1 Input Parameters

Length (m)

This input is the length of the dipole as measured in meters. Any length can be used, but the antenna will be resonant when the length is close to multiples of (2n-1)/2 wavelengths. This parameter will affect the overall shape of the radiation pattern, with shorter lengths producing a much broader pattern.

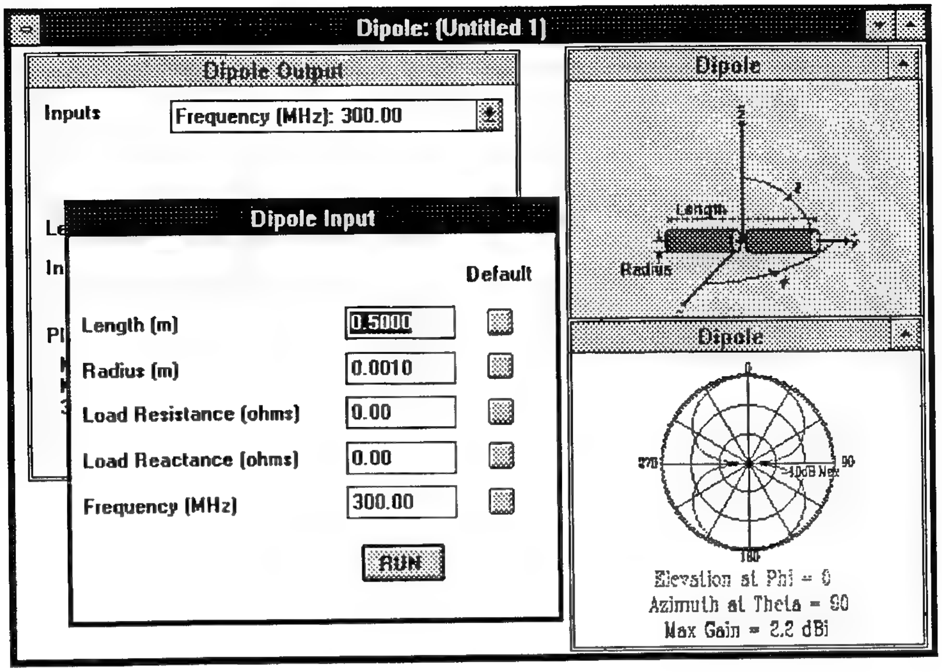

Figure 3.2-6. Dipole Antenna Window

Radius (m)

This input is the radius of the dipole as measured in meters. This parameter will affect the driving-point impedance but will have little impact on the radiation pattern of the dipole antenna. Increasing the radius will result in a wider impedance bandwidth. Note that the radius-to-length ratio must be limited so as not to violate the method of moments algorithm. Error checking will limit this ratio to 1/50. For a larger ratio, the cage dipole module must be used.

Load Resistance (Ohms)

This input allows you to place a load resistor at the feed point of the antenna. By using this input in conjunction with the load reactance, you can load the antenna with any combination of the resistors, inductors, and capacitors.

Load Reactance (Ohms)

This input allows you to place a load reactance at the feed point of the antenna. By using this input in conjunction with the load resistance, you can load the antenna with any combination of the resistors, inductors, and capacitors.

3.2.5.2 Output Parameters

Length (Wavelengths)

The length of the dipole in wavelengths is obtained from its length in meters and the operating frequency as follows:

$$L_W = \frac{L_m \times F}{300}$$

where: L_W = Length in wavelengths

L_m = Length in meters

F = Frequency in MegaHertz

Input Impedance (Ohms)

This is the driving point impedance of the dipole antenna.

3.2.6 E-Flared Horn

An E-flared horn is an aperture antenna that can be thought of as a waveguide with a flared opening at one end. This flared opening is designed to increase the size of the aperture in the E-plane, thus increasing the antenna's directivity in this plane. These aperture antennas are commonly used at microwave frequencies as the feed element for parabolic dish antennas.

Standard techniques for aperture antennas are used to determine the radiation characteristics of the E-flared horn. The tangential components of the fields at the aperture are determined by treating the horn as a radial waveguide and assuming the dominant propagation mode within the waveguide is the TE_{10} mode. Maxwell's equations are then used to solve for the fields on the flared section subject to boundary conditions. This approach results in the following far field patterns:

$$F_h(\theta) = \frac{1+\cos\theta}{2}\left[\frac{\cos(kL_h \sin\theta/2)}{1-(kL_h \sin\theta/\pi)^2}\right]$$

$$F_e(\theta) = \frac{1+\cos\theta}{2}\left\{\frac{[C(r_2)-C(r_1)]^2+[S(r_2)-S(r_1)]^2}{4\left[C^2(2\sqrt{s})+S^2(2\sqrt{s})\right]}\right\}^{\frac{1}{2}}$$

Where F_e and F_h are the far field patterns in the E- and H-planes respectively, and L_e and L_h are the lengths of the horn aperture in the E- and H-planes respectively[6]. C and S are the Fresnel integrals defined as:

$$C(x) = \int_0^x \cos\left(\pi\tau^2/2\right)d\tau \qquad S(x) = \int_0^x \sin\left(\pi\tau^2/2\right)d\tau$$

and s, r_1 and r_2 are defined as:

$$s = \frac{L_e^2}{8\lambda R}$$ where R is the horn's length,

$$r_1 = 2\sqrt{s}\left[-1-\frac{L_e\sin(\theta)}{4\lambda s}\right] \qquad r_2 = 2\sqrt{s}\left[1-\frac{L_e\sin(\theta)}{4\lambda s}\right]$$

[6]W. Stutzman, G. Thiele, Antenna Theory and Design, New York: Wiley & Sons, 1981, pp. 406-411.

The peak gain is computed from:

$$G_{peak} = \frac{32 L_e L_h \left(C^2(q) + S^2(q)\right)}{\pi \lambda^2 q^2}$$

Where q is defined as:

$$q = \frac{L_e}{\sqrt{2\lambda R}}$$

The E-Flared Horn Antenna Window is shown in Figure 3.2-7. Brief descriptions of the input and output parameters required for the E-Flared horn analysis are listed in the following subsections.

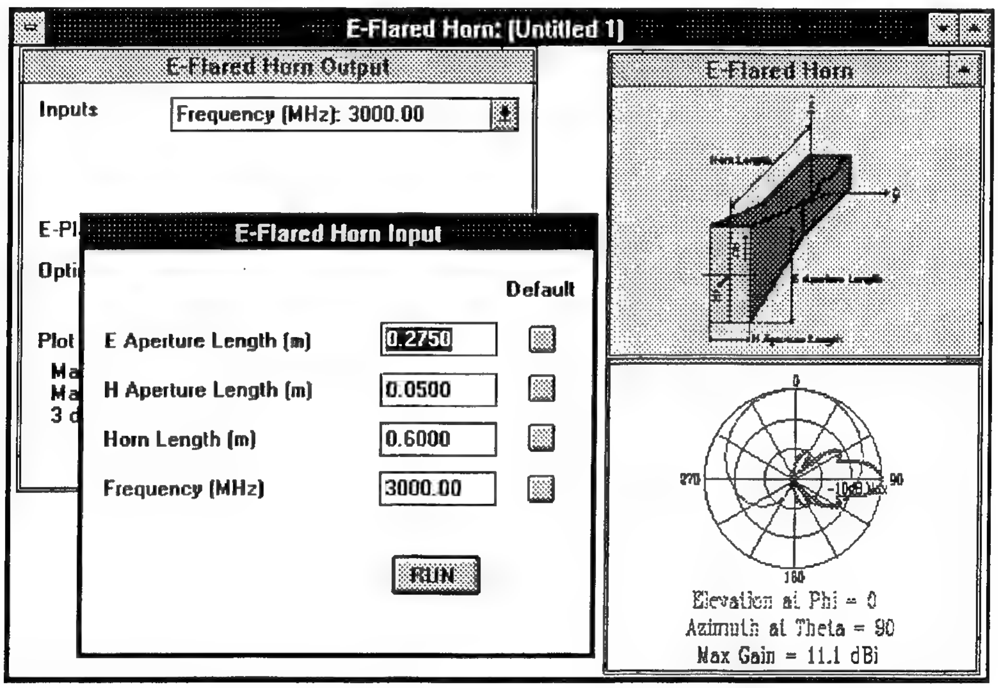

Figure 3.2-7. E-Flared Horn Antenna Window

3.2.6.1 Input Parameters

E-Aperture Length (m)

The E-aperture length is the distance in meters across the horn's aperture in the direction of the E-plane. In an E-flared horn, the E-plane is in the direction of the wider dimension. Because the TE_{10} propagation mode was assumed to exist within the waveguide, the electric field vector at the mouth of the horn lies entirely in the E-plane.

H-Aperture Length (m)

The H-aperture length is the distance in meters across the horn's aperture in the direction of the H-plane. In an E-flared horn, the H aperture length is the narrow dimension of the horn. Refer to the diagram of the E-flared horn for a better understanding of this parameter.

Horn Length (m)

This input is the length in meters from the vertex of the diverging walls to the mouth of the horn. Refer to the diagram of the antenna for a better understanding of this parameter.

3.2.6.2 Output Parameters

E-Plane Phase Error (deg)

This output is the phase error of the horn as measured in the E-Plane. This phase error results from differences in path length that the electromagnetic wave experiences upon reaching the end of the horn. Because of the geometry of the structure, the distance from the source to the center of the horn differs from the distance from the source to the outer edges of the horn. The result is a phase error between the cylindrically propagating wave and a plane wave front emanating from the mouth of the horn. This phase error is calculated as follows:

$$\phi = \frac{2\pi L_e^2}{8\lambda R}$$

Where L_e is the antenna's E-aperture length and R is the Horn's length.

Optimum E Aperture Length (m)

The gain of an ideal aperture antenna increases linearly with the area of the aperture. In an E-flared horn, however, the phase error also increases with the size of the aperture. Large phase errors result in destructive interference which decrease the gain of the antenna. These statements suggest that there is an optimum aperture size that will maximize the gain of the E-flared horn. The optimum E-aperture length is:

$$L_{eopt} = \sqrt{2\lambda R}$$

3.2.7 Fish Bone

The fish bone is traveling wave antenna typically used in receiving applications. It consists of a series of horizontal dipoles positioned in a planar array parallel to the ground. The elements are connected by a common transmission line which runs down the center of the array.

The radiation pattern of the fish bone antenna is determined by combining the pattern of an individual dipole with an array factor term. The individual dipoles are modeled by assuming a sinusoidal current distribution, subject to boundary conditions, along their length. This distribution is then integrated to obtain the radiation pattern. The array factor term, as described in Section 3.2.1, is an interference term that depends only on the relative spacing and phasing of the elements in the array, not on the pattern of the dipoles themselves. To determine the array factor, the user specifies the spacing between adjacent elements and the fish bone module then computes the phase between elements based on free-space propagation. Free-space was used because most fish bone antennas use two wire transmission lines, not coaxials. This phase difference accounts for the propagation delay of the electromagnetic wave as it travels down the transmission line.

As in the case of the array module, the formulation of the radiation pattern assumes no interaction between elements in the array. This assumption is valid for element spacing greater than about one wavelength. For element spacing less than one wavelength the model may provide inaccurate results.

The Fish Bone Antenna Window is shown in Figure 3.2-8. Brief descriptions of the I/O parameters for the fish bone analysis follow.

3.2.7.1 Input Parameters

Number of Elements

The horizontal dipole elements that make up the Fish Bone antenna are oriented in a plane that is parallel to the ground. You must specify the total number of elements in the fish bone array. This input is used in the development of the array factor term which, when combined with a dipole term, produces the radiation pattern of the entire fish bone antenna.

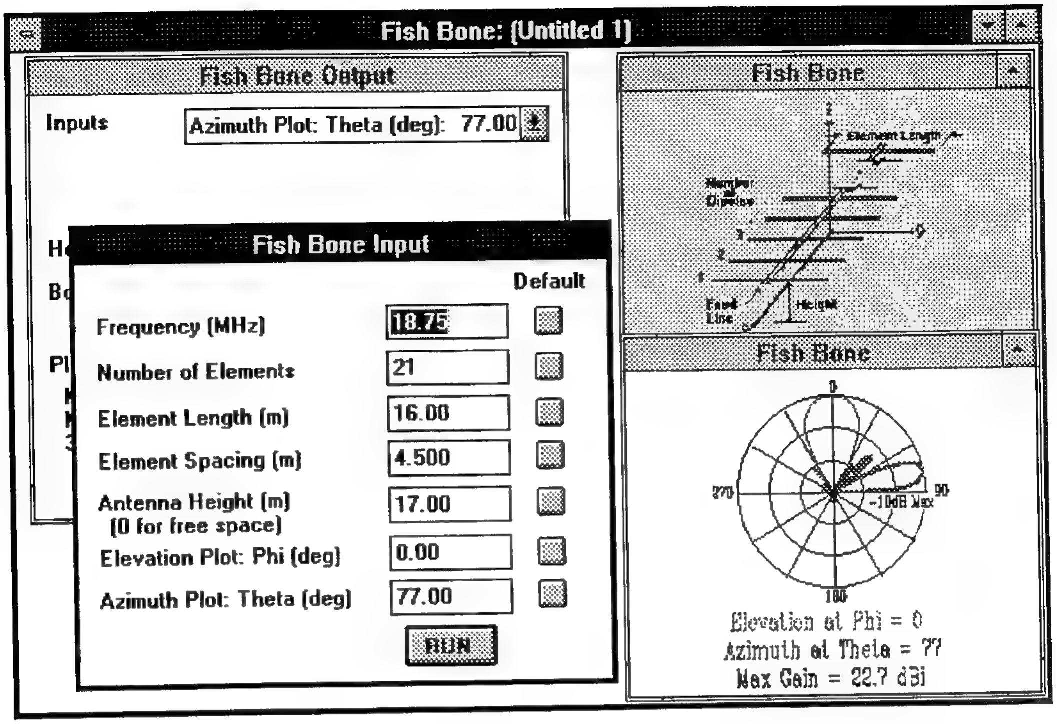

Figure 3.2.8. Fish Bone Antenna Window

Element Spacing (m)

This input specifies the distance in meters between elements of the fish bone array. This input is used in the development of the array factor term which, when combined with a dipole term, produces the radiation pattern of the entire fish bone antenna.

Element Length (m)

This input represents the length of the individual dipoles that comprise the fish bone array. The length is used to determine the radiation pattern of an individual dipole element which in turn is used to develop the overall pattern of the fish bone antenna.

Height (m)

This input represents the height of the fish bone array above a perfect ground. Entering a value of zero will assume that no ground plane is present and the antenna is in free space. The perfect ground plane assumption is reasonable because the antenna produces a horizontally-polarized electric field.

3.2.7.2 Output Parameters

Length of Array (Wavelengths)

The size, in wavelengths, of the fish bone array is computed from the frequency, the number of elements and their spacing. The formula used is:

$$L_w = \frac{(N-1) \times S \times F}{300}$$

where: L_w = Length in wavelengths

S = Spacing between elements in meters

N = Number of elements

F = Frequency in Megahertz

Height (Wavelengths)

This output is the height in wavelengths of the fish bone above the ground. It depends only on the height and the operating frequency.

3.2.8 Folded Dipole

The folded dipole antenna is a variation of a conventional dipole where two dipoles are positioned parallel to one another and connected at both ends. In the case of half wavelength elements, this configuration results in a four fold increase in the driving point impedance over a conventional dipole (i.e., approximately 300 Ohms for a folded dipole vs. approximately 75 Ohms for a conventional dipole). The other important difference between a conventional dipole and a folded dipole is that if the two antennas are short in terms of wavelengths, the conventional dipole becomes highly capacitive while the folded dipole becomes highly inductive. Although the impedance is dramatically affected by this change in geometry, the radiation pattern of a folded dipole antenna is similar to that of a conventional dipole.

The performance of the folded dipole antenna is analyzed by using the method of moments to solve Pocklington's integral equation for the current distribution on the wire elements. This current distribution is integrated over the folded dipole elements to obtain the radiation pattern produced by the antenna. The current and voltage at the feed point are used to compute the driving-point impedance of the folded dipole antenna.

For the method of moments to correctly converge, the model must be segmented correctly. The folded dipole has two short connecting segments which force fine segmentation across the two dipole sections. This segmentation results in the folded dipole model consuming almost 40 seconds for a solution on a 486/33 PC.

The Folded Dipole Antenna Window is shown in Figure 3.2-9. Brief descriptions of the input and output parameters required for the folded dipole analysis are listed in the following subsections.

3.2.8.1 Input Parameters

Length (m)

This input parameter represents the length of the folded dipole as measured in meters. Refer to the diagram of the folded dipole antenna for a better understanding of this input parameter.

Height (m)

This input is the height of the antenna above a perfectly conducting ground plane. When the height is equal to zero, the free space radiation pattern of the folded dipole is computed.

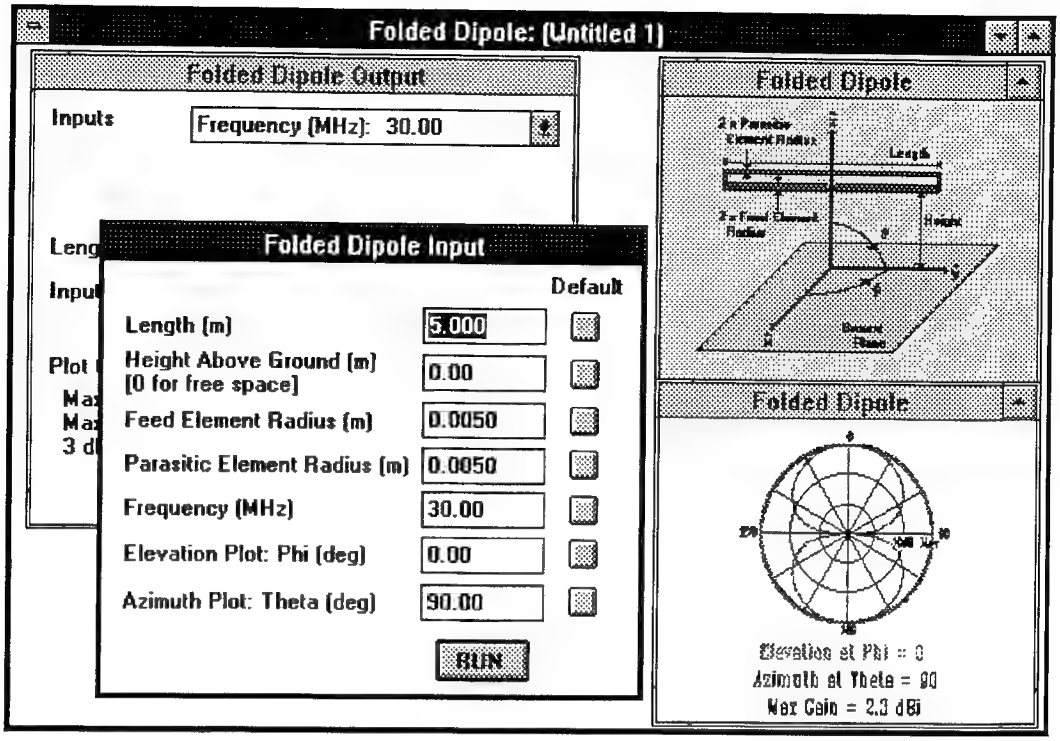

Figure 3.2-9. Folded Dipole Antenna Window

Feed Element Radius (m)

The feed element is connected to the transmission line at the wire's center. This input is the radius in meters of this feed element.

Parasitic Element Radius (m)

This input is the radius, in meters, of the parasitic element.

3.2.8.2 Output Parameters

Length (Wavelengths)

The length of the folded dipole in wavelengths is obtained from its length in meters and the operating frequency.

Input Impedance (Ohms)

This output is the driving point impedance of the folded dipole antenna. Because of the nature of the antenna, the input impedance should be approximately 4 times the impedance of a conventional dipole of similar length.

3.2.9 H-Flared Horn

An H-flared horn is a waveguide with a flared opening at one end. This flared opening is designed to increase the size of the aperture in the H-plane, thus increasing the antenna's directivity in this plane. This type of aperture antenna is commonly used at microwave frequencies as the feed element for parabolic dish antennas.

Standard techniques for aperture antennas are used to determine the radiation characteristics of the H-flared horn. The tangential components of the fields at the aperture are determined by treating the horn as a radial waveguide and assuming the dominant propagation mode within the waveguide is the TE_{10} mode. Maxwell's equations are then used to solve for the fields in the flared section, subject to boundary conditions. This approach is similar to the approach used in the E-Flared horn of Sec. 3.2.6. The far field pattern is computed as [7]:

$$F_e(\theta) = \frac{1+\cos\theta}{2}\left[\frac{\sin(kL_e\sin\theta/2)}{kL_e\sin\theta/2}\right]$$

$$F_h(\theta) = \frac{1+\cos\theta}{2}\left[\frac{I(\theta)}{I(0)}\right]$$

Where F_e and F_h are the far field patterns in the E- and H-planes respectively, and L_e and L_h are the lengths of the horn in the E- and H-planes respectively. I is defined as:

$$\begin{aligned} I(\theta) = & \left[C(s_2) - jS(s_2) - C(s_1) + jS(s_1)\right]e^{j\pi(L_h\sin\theta/\lambda+1/2)^2/8t} \\ & + \left[C(t_2) - jS(t_2) - C(t_1) + jS(t_1)\right]e^{j\pi(L_h\sin\theta/\lambda-1/2)^2/8t} \end{aligned}$$

where C and S are the Fresnel integrals of section 3.2.6 and:

$$t = L_h^2/8\lambda R$$

[7] W. Stutzman, G. Thiele, Antenna Theory and Design, New York: Wiley & Sons, 1981. pp. 399-406.

$$s_1 = 2\sqrt{t}\left[-1 - L_h \sin\theta/(4\lambda t) - \frac{1}{8t}\right] \qquad s_2 = 2\sqrt{t}\left[1 - L_h \sin\theta/(4\lambda t) - \frac{1}{8t}\right]$$

$$t_1 = 2\sqrt{t}\left[-1 - L_h \sin\theta/(4\lambda t) + \frac{1}{8t}\right] \qquad t_2 = 2\sqrt{t}\left[1 - L_h \sin\theta/(4\lambda t) + \frac{1}{8t}\right]$$

The peak gain is given by:

$$G_{peak} = \frac{4\pi L_e R}{\lambda\, L_h}\left\{\left[C(p_1) - C(p_2)\right]^2 + \left[S(p_1) - S(p_2)\right]^2\right\}$$

where

$$p_1 = \frac{1}{\sqrt{2}}\left[\frac{\sqrt{R/\lambda}}{L_h/\lambda} + \frac{L_h/\lambda}{\sqrt{R/\lambda}}\right]$$

$$p_2 = \frac{1}{\sqrt{2}}\left[\frac{\sqrt{R/\lambda}}{L_h/\lambda} - \frac{L_h/\lambda}{\sqrt{R/\lambda}}\right]$$

The H-Flared Horn Antenna Window is shown in Figure 3.2-10. Brief descriptions of the input and output parameters required for the H-Flared horn analysis are listed in the following subsections.

3.2.9.1 Input Parameters

E-Aperture Length (m)

The E-aperture length is the distance in meters across the horn's aperture in the direction of the E-plane. In an H-flared horn, the E-aperture length is in the direction of the narrow dimension.

H-Aperture Length (m)

The H-aperture length is the distance in meters across the horn's aperture in the H-plane. In an H-flared horn, this length is measured across the wider dimension of the horn. Refer to the diagram of the antenna for a more thorough understanding of this parameter.

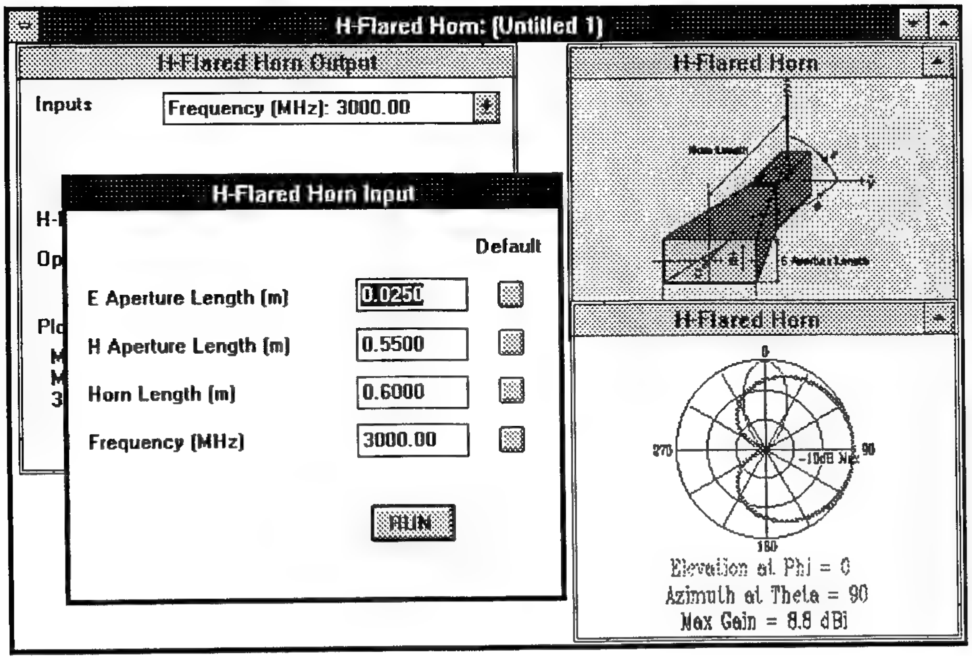

Figure 3.2-10. H-Flared Horn Antenna Window

Horn Length (m)

This input is the length in meters from the virtual vertex of the diverging walls to the mouth of the horn. Refer to the diagram of the antenna for a better understanding of this parameter.

3.2.9.2 Output Parameters

H-Plane Phase Error (deg)

This output is the phase error of the horn as measure in the H-Plane. This phase error results from differences in path length that the electromagnetic wave experiences before reaching the end of the horn. Because of the geometry of the structure, the distance from the source to the center of the horn differs from the distance from the source to the outer edges of the horn. The result is a phase error between the cylindrically propagating wave and the plane wave front emanating from the mouth of the horn. This phase error is calculated as follows:

$$\phi = \frac{2\pi L_h^2}{8\lambda R}$$

Where L_h is the horn's H-aperture length and R is the horn's length.

Optimum H-Aperture Length (m)

The gain of an ideal aperture antenna increases linearly with the area of the aperture. In an H-flared horn, however, the phase error also increases with the size of the aperture. Large phase errors result in destructive interference which decreases the gain of the antenna. These statements suggest that there is an optimum aperture size that will maximize the gain of the H-flared horn. The optimum H-aperture length is: $L_{hopt} = \sqrt{3\lambda R}$

3.2.10 Log Periodic

A log periodic is a broad band antenna made up of a coplanar array of dipoles of varying lengths. The individual dipole elements are connected by a transmission line that runs down the center of the array. A single feed point at the center of the shortest dipole element drives the array. The RF signal travels down the transmission line until it finds elements that are nearly resonant at the driving frequency. These elements, which are close to a half wavelength long, are excited by the RF energy and produce the desired radiation pattern.

The separation and lengths of the individual dipoles result from specific design parameters that are determined from bandwidth and directivity requirements. The two key design parameters are tau (the ratio of the length of adjacent elements) and alpha (half the angle subtended by the array). These parameters are provided as outputs and are described further in many antenna design texts[8],[9].

The approach used to determine the input impedance and radiation pattern of the log periodic is based upon a technique developed by Carrel[10] and described in a book by Ma [11]. The approach determines the relative current (magnitude and phase) at the feed point of each dipole by dividing the array into a collection of the dipole elements and a feeder circuit (i.e. the transmission line). The open circuit impedance matrix represents the interaction between the dipole elements and the short circuit admittance matrix represents the transmission line. The impedance matrix (**Z**) is calculated by assuming a sinusoidal current distribution on each of the elements and using the self- and mutual-impedance equations defined for the cage dipole, Section 3.2.2. The admittance matrix (**Y**) is calculated using standard transmission line techniques[9]. The matrix equation that is solved to determine the dipole base currents can be expressed as:

$$\mathbf{I}_{\mathbf{base}} = (\mathbf{U} + \mathbf{Y}\,\mathbf{Z})^{-1}\,\mathbf{I}_{\mathbf{f}}$$

---

[8] C. A. Balanis, Antenna Theory: Analysis and Design, New York: Harper and Row, 1982,

[9] S. R. Seshadri, Fundermentals of Transmission Lines and Electromagnetic Fields, MA, Addison-Wesley, 1971

[10] R. L. Carrel, Analysis and Design of the LPDA, Ph.D. Thesis, Urbana, IL: University of Illinois, 1961.

[11] T. M. MA, Theory and Application of Antenna Arrays, New York: Wiley & Sons, 1974.

Where $\mathbf{I_{base}}$ is a vector containing the dipole base currents, $\mathbf{U}$ is the identity matrix and $\mathbf{I_f}$ is the source current which is defined as:

$$\mathbf{I}_f = \begin{bmatrix} 1 \\ 0 \\ \vdots \\ 0 \end{bmatrix}$$

The driving-point impedance of the LPDA is determined by multiplying the feed point currents with the appropriate elements of the impedance matrix.

$$Z_{driving} = \frac{V_1}{I_1} = V_1 = Z_{11} I_{1base} + Z_{12} I_{2base} + \cdots + Z_{1N} I_{Nbase}$$

The electric field radiated by the LPDA is the sum of the fields radiated by the individual dipole elements. Individual dipole fields are computed by assuming a sinusoidal current distribution and integrating the fields produced by a hertzian dipole over the length of the dipole. For a vertically oriented dipole, this integration yields:

$$E_{\theta i}(\theta) = j\eta \frac{I_{ibase} e^{-jkr}}{2\pi r} \left[\frac{\cos\left(\frac{kl_i}{2}\cos(\theta)\right) - \cos\left(\frac{kl_i}{2}\right)}{\sin(\theta)} \right]$$

where $E_{\theta i}$ is the θ component of the electric field generated by the i^{th} element and $\mathbf{I_{ibase}}$ is the base current of the dipole under consideration (i.e., one element of the $\mathbf{I_{base}}$ vector which was computed above).

Of course, the phase difference between elements must be considered when the fields are added. The base currents are complex values which reflect the amplitude and phase relationship between elements and directly determine the total electric field at a distant point. The path length differences between rays arriving from different elements result in phase differences which must also be included. The total field radiated by the LPDA is then given by:

$$E_\theta(\theta,\phi) = \sum_{i=1}^{N} E_{\theta i}(\theta) e^{jkd_i \sin(\theta)\cos(\phi)}$$

where d_i is the spacing from the phase center.

Once the electric field radiated by the LPDA has been obtained, the time averaged Poynting vector and the power gain pattern may be computed.

The Log Periodic Antenna Window is shown in Figure 3.2-11. Brief descriptions of the input and output parameters required for the LPDA analysis are listed in the following subsections.

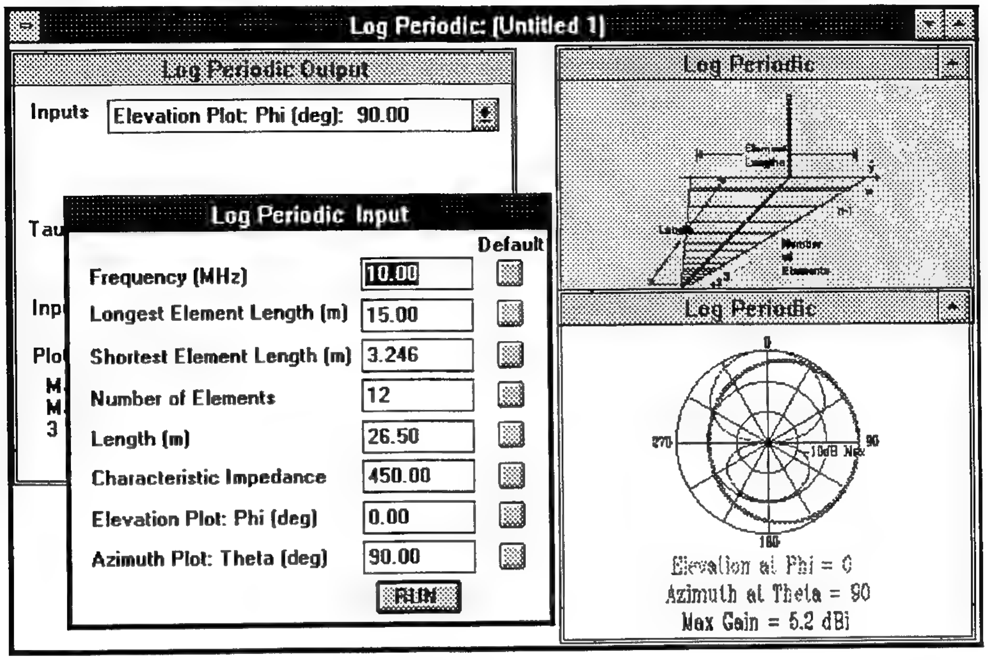

Figure 3.2-11. Log Periodic Antenna Window.

3.2.10.1 Input Parameters

Longest Element Length (m)

A log periodic antenna consists of a number of parallel dipole elements of varying lengths that are arranged in order of increasing size. At one end of the array is the shortest element, at the other end is the longest element. This parameter represents the length (in meters) of the longest element in the LPA array.

Shortest Element Length (m)

This parameter represents the length (in meters) of the shortest element in the LPA array.

Number of Elements

This parameter represents the number of dipole elements in the array.

Antenna Length

This parameter represents the distance (in meters) between the longest and the shortest elements in the log periodic array.

Transmission Line Impedance (Ohms)

The individual dipole elements that comprise the log periodic antenna are connected by a transmission line. This parameter represents the characteristic impedance of that transmission line.

3.2.10.2 Output Parameters

Tau

In a log periodic array, the lengths, spacing and diameters of the dipole elements increase geometrically by the geometric ratio Tau. Tau is an LPA design parameter which represents the ratio of the lengths of adjacent elements. It also represents the ratio of the diameters of adjacent elements and the ratio of the distances of adjacent elements from a fixed point.

Alpha

Frequency independent antennas are usually characterized by an angle. In the case of the log periodic antenna, this angle is alpha. If two lines are drawn to connect the ends of the elements on each side of the LPA, the lines will converge to form an angle. Alpha is defined to be half this angle. Alpha is a design parameter which is selected to meet bandwidth and directivity requirements.

Input Impedance (Ohms)

This output is the driving-point impedance of the LPA antenna. If the input frequency is properly matched to the antenna, the input impedance should be close to the characteristic impedance of the transmission line selected as an input.

3.2.11 Long Wire

In a long wire antenna, the electromagnetic energy generated by the exciter and imparted to the antenna travels down the antenna. Any energy that has not been radiated by the time it reaches the end of the antenna is completely dissipated by a terminating resistor. This situation results in a traveling wave current distribution which contrasts the standing wave of a conventional dipole antenna, Section 3.2.5.

A closed form expression is used to analyze the performance of the long wire antenna. The method used to derive the closed form solution for a horizontal long wire is similar to the method Wolf[12] used for a for a vertical long wire. Given the current distribution, one can calculate the curl of the magnetic vector potential for the magnetic field. Solution of the Poynting vector combined with the power of an isotropic yields the following gain equation:

$$G(\theta,\phi)=\frac{120}{R_r}\frac{\left(\sin^2\phi+\cos^2\theta\cos^2\phi\right)\sin^2\left[{kl}/{2}\left(1-\sin\theta\cos\phi\right)\right]}{\left(1-\sin\theta\cos\phi\right)^2}$$

The resulting radiation pattern is integrated over a closed sphere to determine the total power radiated, and thus, the radiation resistance of the long wire. For this assumption to be valid, the antenna must operate at close to 100% efficiency. The equation for the radiation resistance is shown here:

$$R_r=60\left[1.415+\ln\left({kl}/{\pi}\right)-C_i(2kl)+{\sin(2kl)}/{(2kl)}\right]$$

where C_i is the cosine integral given is Section 3.2.2.

The Long Wire Antenna Window is shown in Figure 3.2-12. Brief descriptions of the input and output parameters required for the long wire analysis are listed in the following subsections.

12 E.A. Wolf, Antenna Analysis, New York: Wiley & Sons, 1966, pp. 372-379.

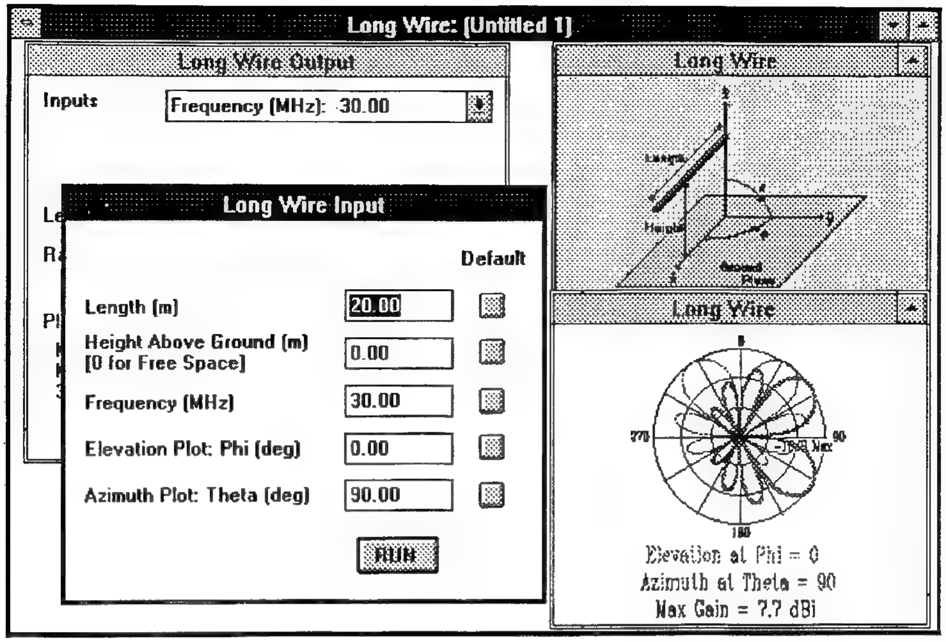

Figure 3.2-12. The Long Wire Antenna Window.

3.2.11.1 Input Parameters

Length (m)

This input is the length of the long wire antenna as measured in meters. This parameter will affect the antenna's radiation pattern and the radiation resistance.

Height (m)

Long wire antennas are typically oriented horizontally over the ground. This input is the height of the antenna above a perfectly conducting ground plane. Entering a value of zero will cause the program to ignore the presence of the ground plane, analyzing it in free space.

3.2.11.2 Output Parameters

Length (Wavelengths)

This is the length of the antenna as measured in wavelengths. It depends only on the antenna's length in meters and the excitation frequency.

Radiation Resistance (Ohms)

This output is the radiation resistance at the input terminals of the long wire antenna. It is computed from the total radiated power which is obtained by integrating the antenna's radiation pattern over a closed spherical surface.

3.2.12 Loop

A circular loop is a convenient antenna for many applications; Electrically small loops are employed as receive antennas, while larger loops can be employed as transmit or receive antennas. Small loops have very low radiation resistance and therefore appear to the transmitter as a short circuit. Analysis of small loops can be performed assuming uniform current distribution around the loop. Larger loops have a more complex current distribution and so analysis is much more difficult. Because the wide range of performance is a function of loop size, two approaches have been developed to handle the small and large loop cases separately.

It can be shown that in the limiting case, a small loop is equivalent to an infinitesimal magnetic dipole. Using this simplification, straight-forward, closed form solutions can be developed for radiation patterns of small loop antennas. These approximations show very good agreement with measurements as long as the loop radius is less than 0.03 wavelengths. For these loops, the gain and radiation resistance are computed with the following equations[13]:

$$G = \frac{3}{2}\sin^2(\theta)$$

$$R_r = 20\pi^2\left(\frac{2\pi r}{\lambda}\right)^4$$

where r is the loop's radius.

Because there is no acceptable closed form solution for the analysis of large loop antennas, the loop module uses a method of moments approach for loops with radii greater than or equal to 0.03 wavelengths. In this approach, Pocklington's integral equation is solved numerically to determine the current distribution on the loop antenna. Integrating over this current distribution produces the radiation pattern of the antenna.

The Loop Antenna Window is shown in Figure 3.2-13. Brief descriptions of the input and output parameters required for the loop analysis are listed in the following subsections.

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13 C. A. Balanis, Antenna Theory: Analysis and Design, New York: Harper and Row, 1982, pp. 164-184

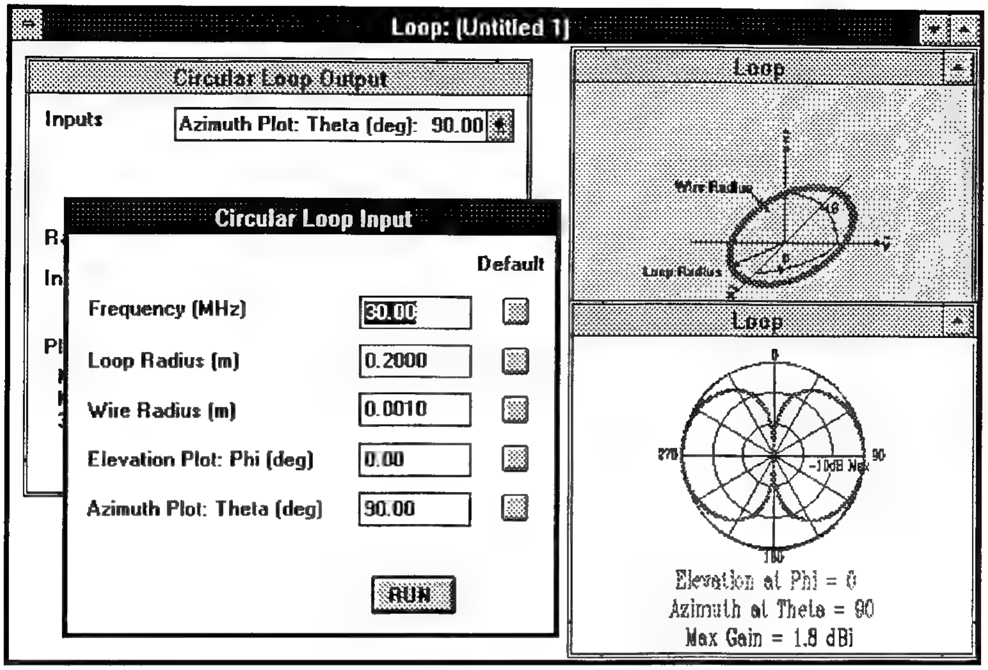

Figure 3.2-13. The Loop Antenna Window

3.2.12.1 Input Parameters

Loop Radius (m)

This parameter is the radius of the loop in meters. The value of this parameter has a significant impact on the performance of the antenna. The loop radius is also used to determine which approach to use to solve for the radiation pattern. For loop radii less than 0.03 wavelengths, a closed form solution is used, for larger radii, a method of moments approach is employed.

Wire Radius (m)

This input is the radius of the wire that the makes up the loop.

3.2.12.2 Output Parameters

Loop Radius (Wavelengths)

This output parameter is the radius of the loop measured in wavelengths.

Input Impedance (Ohms)

This value is the feed or driving point impedance of the antenna. For loop radius values of less than 0.03 wavelengths a closed form solution is used to determine the impedance of the antenna. For larger values, a method of moments approach is used.

3.2.13 Monopole

Monopoles are used as transmitting and receiving antennas in many applications because of their simplicity of design and their omni-azimuthal coverage. A monopole is simply a thin wire positioned vertically with respect to a ground plane. It is driven by a transmission line connected between the bottom of the wire and the ground plane. This geometry produces a vertically-polarized, omni-azimuthal electric field pattern. A monopole antenna positioned over a perfectly-conducting, infinite ground plane produces a radiation pattern in the upper half-space which is identical in shape to a dipole but has an additional 3 dB of gain. This additional gain is achieved by virtue of the complete reflection of the electric field by the perfectly-conducting, infinite ground plane.

The monopole antenna is analyzed by using the method of moments technique to solve Pocklington's integral equation for the current distribution on the thin wire element. Standard techniques are then used to integrate over this current distribution to determine the radiation pattern and the driving-point impedance of the monopole antenna. In determining the performance of this antenna, a perfectly-conducting, infinite ground plane was assumed.

The Monopole Antenna Window is shown in Figure 3.2-14. Brief descriptions of the input and output parameters required for the monopole analysis are listed in the following subsections.

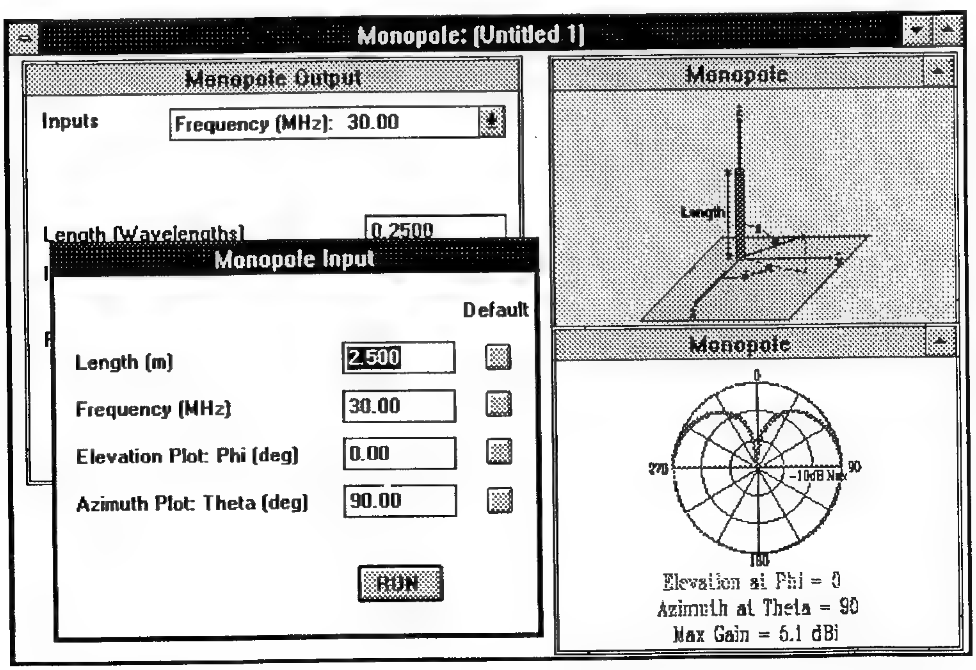

Figure 3.2-14. The Monopole Antenna Window

3.2.13.1 Input Parameters

Length (m)

This input is the length of the monopole is meters. Typical transmitting monopole antennas are approximately 1/4 wavelengths long. For receiving antennas, any length can be used with the understanding that a mismatch loss will result from different impedances of the transmission line and antenna.

3.2.13.2 Output Parameters

Length (Wavelengths)

The length of the monopole in wavelengths is obtained from its length in meters and the operating frequency.

Input Impedance (Ohms)

This output is the driving-point impedance of the monopole antenna. The driving-point impedance should be matched to the transmission line impedance to avoid mismatch losses

3.2.14 Parabolic Reflector

Parabolic reflector antennas are widely used for satellite and line-of-site links which require UHF and SHF frequencies. Their popularity is derived from their highly-directional radiation pattern. They are not used at lower frequencies (i.e. HF and VHF) because the size of the required dish is not practical. The antenna consists of a parabolically shaped reflecting surface and a feed element. Energy from the feed element is reflected by the paraboloid and focused into a narrow, collimated beam. Ideally, the feed element would distribute all its energy uniformly over the surface of the paraboloid. In reality, energy is distributed over the dish unequally with some of the energy actually spilling over the edges.

Geometrical optics are used to derive a closed form expression for the radiation pattern produced by the parabolic reflector. This technique requires knowledge of the distribution of energy on the surface of the dish as produced by the feed. This feed pattern is assumed to be closely approximated by a cosine function raised to the nth power. This was chosen because it represents the major part of most practical antenna feeds. The feed pattern can be expressed by the following equation[14]:

$$G_{feed}(\theta) = 2(n+1)\cos^n \theta$$

The argument of this cosine function (θ) is the angle made by the feed element, the center of the dish, and the point on the dish in question. The power that the cosine is raised to is user selectable to provide flexibility in generating a feed with a focused or wide beam to illuminate the dish. The gain and 3 dB beamwidth of the parabolic dish antenna are computed[14] as:

$$G_{peak} = \left(\frac{\pi d}{\lambda}\right)^2 A_e \qquad BW = \sqrt{33700 / G_{peak}}$$

where d is the dish diameter and the aperture efficiency, A_e, is

$$A_e = \cot^2\left(\frac{\theta_0}{2}\right)\left|\int_0^{\theta_0} \sqrt{G_{feed}(\theta')}\tan\frac{\theta'}{2}\,d\theta'\right|^2$$

$$\theta_0 = \tan^{-1}\frac{d}{2\left(f - d^2/16f\right)}$$

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14 C. A. Balanis, Antenna Theory: Analysis and Design, New York: Harper and Row, 1982, pp. 607-632.

This antenna has a highly directive, narrow, main beam. This results in poor visual resolution in the standard Quick-Look radiation pattern plot. The plot, however, is still correct, and more precise values can be read from the text output window.

The Parabolic Reflector Antenna Window is shown in Figure 3.2-15. Brief descriptions of the input and output parameters required for the parabolic reflector analysis are listed in the following subsections.

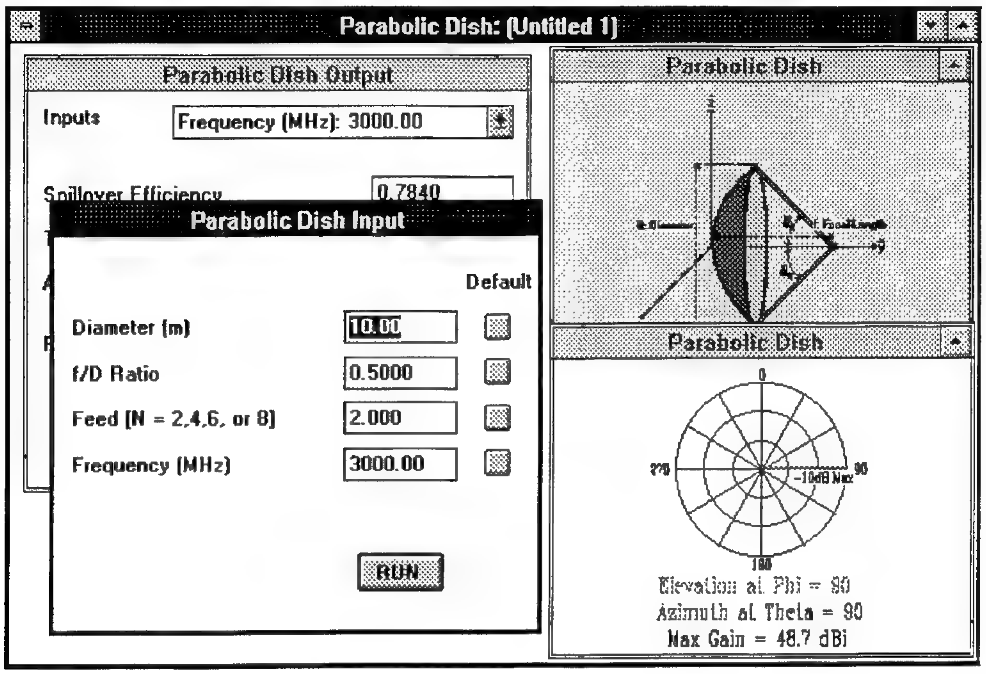

Figure 3.2-15. The Parabolic Dish Antenna Window.

3.2.14.1 Input Parameters

Diameter (m)

This input is the diameter of the dish as measured in meters. A larger diameter will result in a more focused radiation pattern.

f/D Ratio

This input is a measure of the curvature of the dish. The focal length, f, is the distance from the dish to the focal point. The feed is positioned at the focal point so that all the energy emanating from it will be reflected by the dish.

Feed (N = 2, 4, 6, 8)

This input parameter controls the distribution of energy produced by the feed element. Increasing **N** will increase the focus of the feed pattern, thus concentrating the illumination closer to the center of the dish.

Decreasing **N** will spread the energy more evenly over the dish. Decreasing N too much may cause some of the energy to be wasted by spilling it over the edges of the dish.

3.2.14.2 Output Parameters

Spillover Efficiency

The spillover efficiency is a measure of the energy that misses the dish, spilling over its edges. It is defined as the ratio of the energy reflected by the dish to the total energy that is emitted by the feed. This output parameter is affected by the feed exponent (**N**). Increasing **N** will produce a more focused feed pattern that will minimize the energy spilling over the dish's edges, thus maximizing the spillover efficiency.

Taper Efficiency

This output is defined as the ratio of the aperture efficiency to the spillover efficiency.

Aperture Efficiency

The aperture efficiency is the ratio of the actual area of the aperture to its effective area. It is a measure of the antennas ability to efficiently collect (or transmit) RF energy.

3.2.15 Pyramidal Horn

A pyramidal horn is a combination of an E- and H-flared horn. This antenna can be thought of as a rectangular waveguide with both walls flared at one end. This flared opening is designed to increase the size of the aperture, thus increasing the antenna's directivity. The amount and direction of the flare has a profound effect on the performance of the antenna. Pyramidal horns differ from E- and H-flared horns in that they are flared in both principal planes. They are commonly used in satellite applications as the feed element for parabolic dish antennas.

Standard techniques for aperture antennas are used to determine the radiation characteristics of the pyramidal horn. The tangential components of the fields at the aperture are determined by treating the horn as a radial waveguide and assuming the dominant propagation mode within the waveguide is the TE_{10} mode. Maxwell's equations are then used to solve for the fields in the flared section, subject to boundary conditions, resulting from the E- and H-aperture dimensions independently. This approach assumes that the aperture is larger than one wavelength in both principal planes. If the aperture of the antenna is large enough, then the fields radiated in the H-Plane (E-Plane) will depend only on the aperture in H-Plane (E-plane). This statement implies that the H-plane (E-Plane) pattern of the pyramidal horn is the same as the H-plane (E-Plane) pattern of a similar H-flared (E-flared) horn. This approach for analyzing the pyramidal horn[15] results in a peak gain of:

$$G_{peak} = \frac{\pi\lambda^2}{32 L_e L_h} G_{E-peak} G_{H-peak}$$

Where L_e and L_h are the lengths of the horn in the E- and H-Planes respectively, and $G_{E\text{-}peak}$ and $G_{H\text{-}peak}$ are the peak gains for the E- and H-Flared horns described in sections 3.2.6 and 3.2.9 respectively.

The Pyramidal Horn Antenna Window is shown in Figure 3.2-16. Brief descriptions of the input and output parameters required for the pyramidal horn analysis are listed in the following subsections.

[15] W. Stutzman, G. Thiele, Antenna Theory and Design, New York: Wiley & Sons, 1981 pp. 411-412.

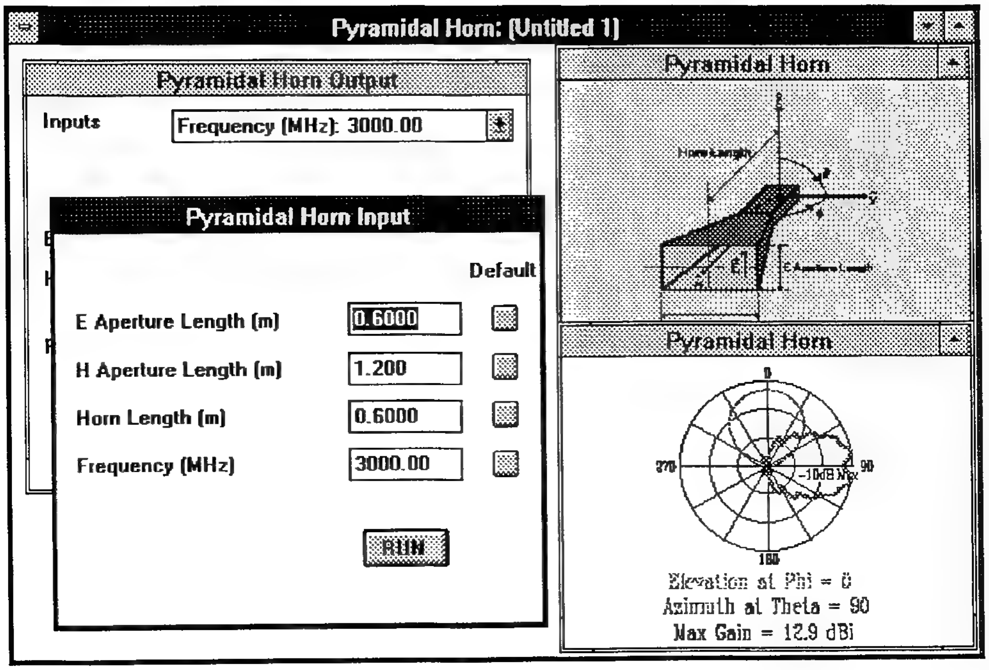

Figure 3.2-16. Pyramidal Horn Antenna Window.

3.2.15.1 Input Parameters

E-Aperture Length (m)

This input is the length of the horn (in meters) in the direction of the E-plane. The electric field vector at the mouth of the horn points in the direction of the E-plane because the TE_{10} mode was assumed to be the dominant propagation mode within the waveguide. Refer to the diagram of the antenna for a better understanding of this parameter.

H-Aperture Length (m)

This input is the length of the horn (in meters) in the direction of the H-plane. The H-plane is perpendicular to the E-plane at the mouth of the horn. Since the TE_{10} propagation mode was assumed, the electric field vector at the mouth of the horn is perpendicular to the H-plane. Refer to the diagram of the antenna for a better understanding of this parameter.

Horn Length (m)

This input is the length in meters from the virtual vertex of the diverging walls to the mouth of the horn. Refer to the diagram of the antenna for a better understanding of this parameter.

3.2.15.2 Output Parameters

E-Plane Phase Error (deg)

This output is the phase error of the pyramidal horn as measured in the E-Plane. This phase error results from differences in path length that the electromagnetic wave experiences before reaching the end of the horn. Because of the geometry of the structure, the distance from the source to the center of the horn differs from the distance from the source to the outer edges of the horn. This path length difference results in a phase error exhibited by the plane wave front emanating from the mouth of the horn.

H-Plane Phase Error (deg)

This output is the phase error of the pyramidal horn as measured in the H-Plane. This phase error results from differences in path length that the electromagnetic wave experiences before reaching the end of the horn. Because of the geometry of the structure, the distance from the source to the center of the horn differs from the distance from the source to the outer edges of the horn. The result is a phase error exhibited by the plane wave front emanating from the mouth of the horn.

3.2.16 Rectangular Aperture

This aperture antenna consists of a rectangular hole cut into an perfectly-conducting, infinite metal plate. This antenna is typically used at microwave frequencies for conformal antenna designs. Aircraft, for example, often use rectangular apertures because they can be easily cut into the side of the plane and covered with a dielectric. This configuration provides a smooth surface that will not affecting the aerodynamics of the plane.

A rectangular aperture can be excited in a number of different ways. Each excitation method produces a different electric field distribution over the surface of the aperture. The Quick-Look module includes two of the most useful excitation modes; uniform and TE_{10}. In the uniform excitation mode, the electric field is constant in both principal planes (i.e., E, and H). In the TE_{10} mode, the fields are constant in the E-Plane, but sinusoidal in the H-plane.

The performance of the rectangular aperture antenna is analyzed through the use of the field equivalence principle[16]. Defining the dimensions of the aperture in the X and Y directions as a and b respectively, and assuming a uniform excitation, this technique results in a gain function of:

$$G_{uniform}(\theta,\phi) = C\left\{\left(\sin(\phi)\frac{\sin X'}{X'}\frac{\sin Y'}{Y'}\right)^2 + \left(\cos(\theta)\cos(\phi)\frac{\sin X'}{X'}\frac{\sin Y'}{Y'}\right)^2\right\}$$

where

$$C = 4\pi\frac{ab}{\lambda^2}$$

$$X' = \frac{ka}{2}\sin\theta\cos\phi$$

$$Y' = \frac{kb}{2}\sin\theta\sin\phi$$

For TE_{10} mode excitation, the gain becomes:

16 C. A. Balanis, Antenna Theory: Analysis and Design, New York: Harper and Row, 1982, pp. 457-478.

$$G_{TE_{10}}(\theta,\phi)=\frac{\pi^2}{2}C\left\{\left(\sin(\phi)\frac{\cos X'}{(X')^2-\left(\frac{\pi}{2}\right)^2}\frac{\sin Y'}{Y'}\right)^2+\left(\cos(\theta)\cos(\phi)\frac{\cos X'}{(X')^2-\left(\frac{\pi}{2}\right)^2}\frac{\sin Y'}{Y'}\right)^2\right\}$$

The Rectangular Aperture Antenna Window is shown in Figure 3.2-17. Brief descriptions of the input and output parameters required for the rectangular aperture analysis are listed in the following subsections.

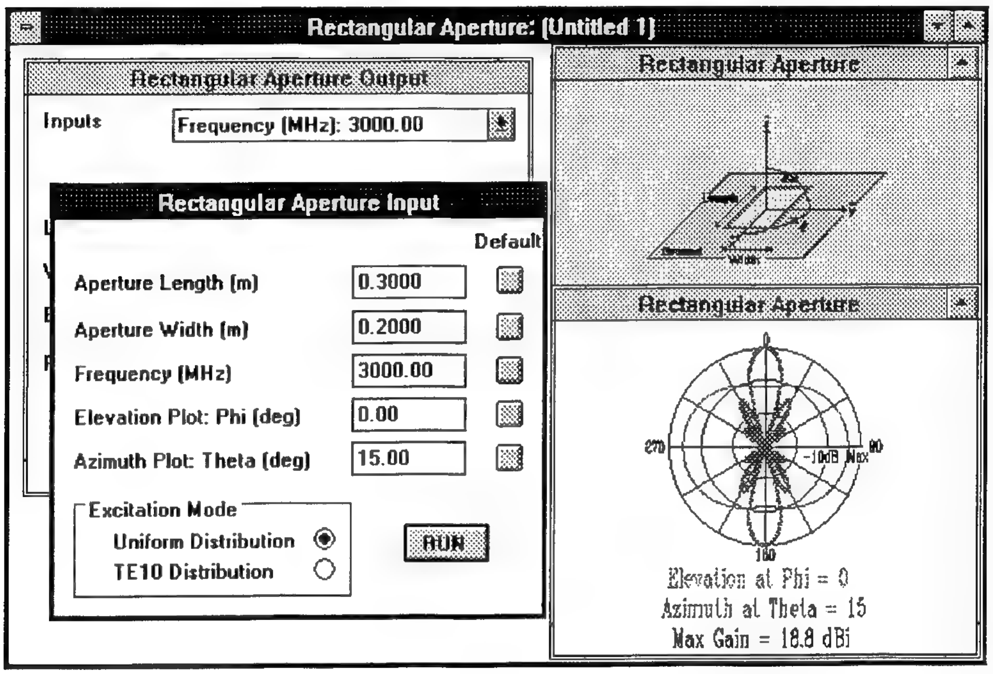

Figure 3.2-17. The Rectangular Aperture Antenna Window.

3.2.16.1 Input Parameters

Length (m)

This input is the length of the aperture as measured in meters along the X-axis. Refer to the diagram of the antenna for a better understanding of this parameter.

Width (m)

This input is the width of the aperture as measured in meters along the Y-axis. Refer to the diagram of the antenna for a better understanding of this parameter.

Excitation Mode - Uniform Distribution

This module provides the flexibility to select the excitation mode of the rectangular aperture as either a uniform or a TE_{10} propagation mode. In the uniform mode, a constant electric field is assumed at all points along the surface of the aperture. This distribution is physically unrealizable for an actual aperture because it violates the boundary conditions. The uniform distribution mode does, however, provide insight which is useful for the analysis of more complex antennas.

Excitation Mode - TE_{10} Distribution

In the TE_{10} mode, a sinusoidal field distribution is assumed. This mode provides an accurate distribution to satisfies all boundary conditions.

3.2.16.2 Output Parameters

Length (Wavelengths)

The output is the length of the aperture as measured in wavelengths. It depends only on the length in meters and on the excitation frequency.

Width (Wavelengths)

The output is the width of the aperture as measured in wavelengths. It depends only on the width in meters and on the excitation frequency.

Excitation Mode

This output allows you to view which excitation mode was used for the calculations, the two options are uniform distribution and TE_{10}

3.2.17 Rhombic

A rhombic antenna is a traveling wave antenna shaped like a rhombus. It can be thought of as two equal length long wire antennas which diverge from the feed point and bend at the center to converge at the end point. The antenna is fed at the diverging vertex and terminated with a 600-800 Ω resistor at the converging vertex. When the vertex angles are chosen correctly, this arrangement of long wire antennas forms a uni-directional radiation pattern .

The rhombic algorithm uses closed form expressions for the radiation intensity and the radiation resistance. The equations are based on four long wire antennas at different positions and angles. The radiation intensity is integrated over 4π steradians to obtain the total power radiated. Assuming that only a small amount of power is lost in the termination, the radiation resistance is found using the total radiated power. For this assumption to be valid, the antenna must operate at close to 100% efficiency.

The gain of Rhombic is computed from the following closed form solution[17]:

$$G(\theta,\phi) = \frac{120\sin^2\phi_0 \sin^2\left(\frac{kl\Psi_1}{2}\right)\sin^2\left(\frac{kl\Psi_2}{2}\right)}{\pi\Psi_1\Psi_2}$$

with

$$\Psi_1 = \left[1 - \sin\theta\cos(\phi + \phi_0)\right]$$

$$\Psi_2 = \left[1 - \sin\theta\cos(\phi - \phi_0)\right]$$

The radiation resistance is given by:

$$R_A = 240\left(\ln\left(2kl\sin^2\phi_0\right) + 0.577\right)$$

The Rhombic Antenna Window is shown in Figure 3.2-18. Brief descriptions of the input and output parameters required for the rhombic antenna analysis are listed in the following subsections.

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[17] S. Ramo, J. Whinnery, Fields and Waves in Modern Radio, New York: Wiley & Sons, 1944, pp. 463-466.

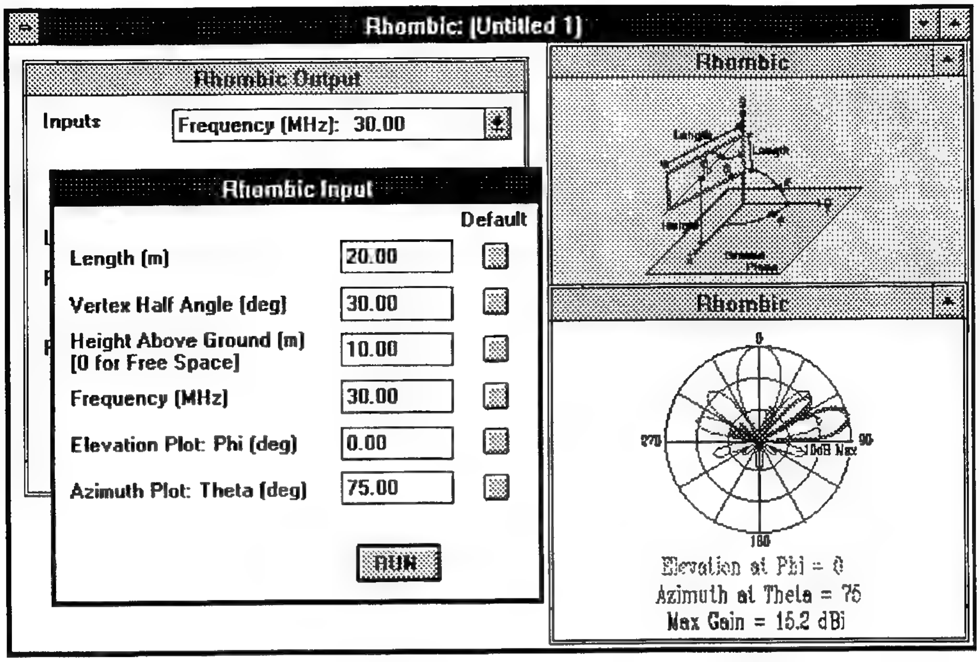


Figure 3.2-18. The Rhombic Antenna Window.

3.2.17.1 Input Parameters

Length (m)

This input represents the length in meters of each arm of the rhombic antenna. Because the antenna has the shape of a rhombus, each of the four arms are of equal length. Changing this parameter will impact the radiation pattern of the antenna.

Vertex Half Angle (deg)

A rhombic antenna is composed of four long wire antennas which are arranged in the shape of a rhombus. It is necessary to specify the interior angles and the length of each side to completely specify the geometry of the rhombic antenna. Since the interior angles consist of a pair of complimentary angles, only one angle is required. This input is half of the angle formed at the driven end of the rhombic antenna. Changing this parameter will impact the radiation pattern of the antenna.

Height (m)

Rhombic antennas are typically oriented horizontally above ground. This input represents the height in meters of the rhombic above the ground. Entering a value of zero will assume no ground plane is present and the antenna is in free space.

3.2.17.2 Output Parameters

Length (Wavelengths)

This output is the length in wavelengths of each of the four long wires which comprise the rhombic antenna. It depends only on the radiating frequency and on the length in meters of the long wires.

Radiation Resistance (Ohms)

This output is the radiation resistance (i.e., the real part of the impedance) that would be seen by a transmission line connected to the antenna's input terminals.

3.2.18 Thin Slot Aperture

A thin slot aperture antenna is nothing more than a narrow slot cut into a conducting sheet of metal. The slot can be excited by a coaxial transmission line which has its center conductor and shield connected to opposite sides of the slot's center. This configuration results in an electric field that is perpendicular to the length of the slot and approximately sinusoidal in magnitude. Because this electric field is identical to the magnetic field that is created by a dipole, the thin slot is the dual antenna of a dipole. The difference between these dual antennas is that the electric and magnetic fields are interchanged, which results in a change in the polarization of the radiated fields. A vertical dipole antenna , for example, has an electric field pattern that is purely in the theta direction. The electric field of a vertical thin slot antenna, on the other hand, only has a phi component.

The power gain pattern of any antenna is a function of the time averaged Poynting vector. The Poynting vector is defined as the cross product of the electric and magnetic field vectors. Because the dipole and the slot antennas produce electric and magnetic fields that are interchanged, the thin slot antenna has a power gain pattern that is identical to the pattern of a dipole, which can be expressed as:

$$G(\theta,\phi)=G_{\theta}(\theta)=\frac{120}{R_{self}}\left[\frac{\cos\left(\frac{kl}{2}\cos(\theta)\right)-\cos\left(\frac{kl}{2}\right)}{\sin(\theta)}\right]^2$$

Where R_{self} is the radiation resistance of a dipole of length l which is computed as described for the cage dipole of section 3.2.2.

The relationship between the input impedance of the dipole and the thin slot is defined by:

$$Z_s=\frac{\eta^2}{4Z_d}$$

where Z_S = Input point impedance of a slot antenna

Z_d = Input point impedance of a dipole antenna of equal length

η = impedance of free space (120π)

For a half wavelength thin slot, this expression results in a radiation resistance of about 485 ohms.

The technique used to analyze this antenna assumes that the slot is cut into a perfectly-conducting surface that is infinite in extent. This approximation is necessary to avoid the fringe effects that are caused by the edges of surface.

The Thin Slot Aperture Antenna Window is shown in Figure 3.2-19. Brief descriptions of the input and output parameters required for the thin slot aperture analysis are listed in the following subsections.

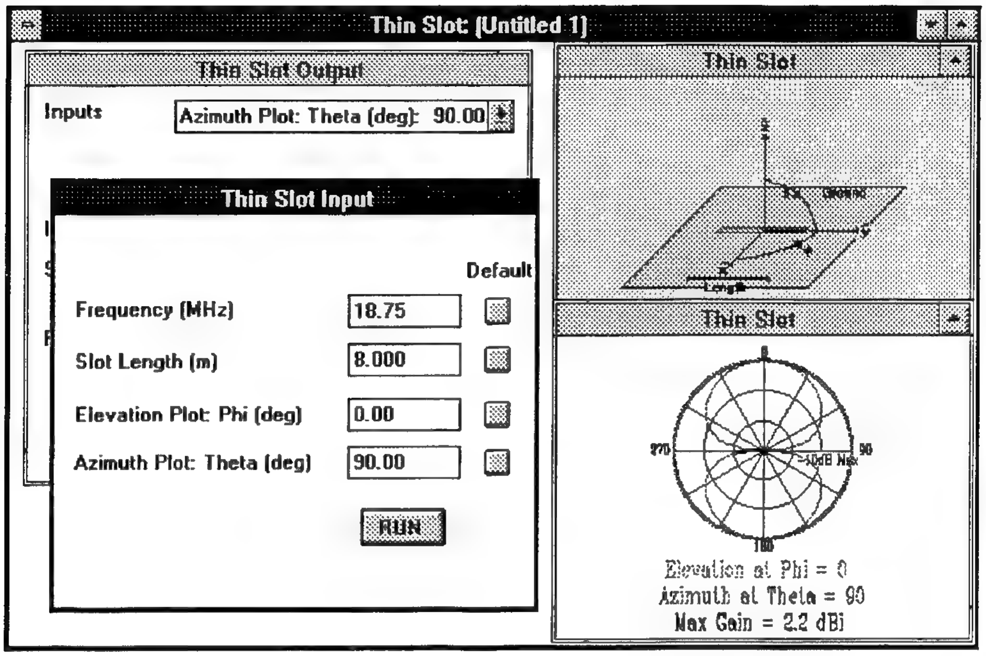


Figure 3.2-19. The Thin Slot Aperture Antenna Window.

3.2.18.1 Input Parameters

Length (m)

This parameter represents the length of the thin slot aperture. Refer to the illustration for a better understanding of this parameter.

3.2.18.2 Output Parameters

Slot Length (Wavelengths)

This output represents the length of the slot when measured in wavelengths. The antenna will be close to resonant when the slot is about 1/2 wavelength long.

Input Impedance (Ohms)

This output represents the impedance of the slot antenna as measured at its input terminals.

3.2.19 VEE

A VEE antenna is an arrangement of two traveling-wave long wire antennas which are positioned to form a uni-directional radiation pattern. Each of the long wires is terminated with a resistive load to prevent reflections which would result in a standing wave pattern. A single traveling wave long wire antenna creates a conical radiation pattern which can be characterized by a single vertex half angle (θ_w) that depends upon the length of the wire. Two long wire antennas arranged to form a VEE with half angle (θ_v) produce a uni-directional radiation pattern when θ_v = θ_w. This arrangement results in the addition of the fields along the line that bisects the VEE and cancellation of fields in other directions.

Closed form expressions for the radiation resistance and the gain pattern are used to model the performance of the VEE antenna. The equations are used based on two diverging long wire antennas with each one 180° out of phase. The gain equation for the VEE is expressed as:

$$G(\theta,\phi) = {}^{15}\!/_{R_r}\left(\aleph_1 + \aleph_2\right)$$

where

$$\aleph_1 = \left\{ \frac{\sin^2\left[{}^{kl}\!/_2\left(1-\sin\theta\cos(\phi+\phi_0)\right)\right]}{\left(1-\sin\theta\cos(\phi+\phi_0)\right)^2} \right\} \sin^2(\phi+\phi_0) + \cos^2\theta\cos(\phi+\phi_0)$$

$$\aleph_2 = \left\{ \frac{\sin^2\left[{}^{kl}\!/_2\left(1-\sin\theta\cos(\phi-\phi_0)\right)\right]}{\left(1-\sin\theta\cos(\phi-\phi_0)\right)^2} \right\} \sin^2(\phi-\phi_0) + \cos^2\theta\cos(\phi-\phi_0)$$

This gain pattern was integrated over a closed sphere to obtain the total power radiated and thus the radiation resistance of the VEE antenna. For this assumption to be valid, the antenna must operate at close to 100% efficiency. The radiation resistance is expressed as:

$$R_r = 120\left[\ln\left(150^{\sin\phi_0}\!/_{f\pi a}\right)\right]$$

where f is the frequency and a is the wire radius which is assumed to be 2.0 mm

The VEE Antenna Window is shown in Figure 3.2-20. Brief descriptions of the input and output parameters required for the VEE antenna analysis are listed in the following subsections.

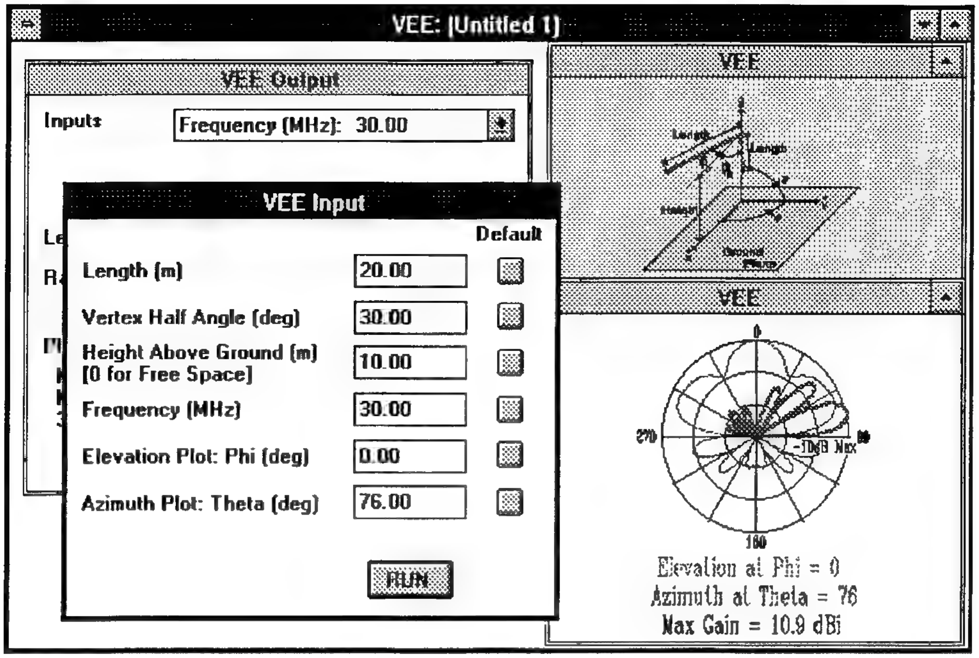


Figure 3.2-20. The VEE Antenna Window.

3.2.19.1 Input Parameters

Length (m)

This input represents the length in meters of each arm of the VEE antenna. These arms are assumed to be of equal length.

Vertex Half Angle (deg)

A VEE antenna is composed of two long wire antennas which are arranged in the shape of the letter "V". This input is half of the angle between the two long wires. Changing this parameter will impact the radiation pattern of the antenna.

Height (m)

VEE antennas are typically oriented horizontally above ground. This input represents the height in meters of the VEE above the ground. If zero is entered in this field, the program will assume no ground plane is present and the antenna is in free space.

3.2.19.2 Output Parameters

Length (Wavelengths)

This output is the length in wavelengths of the individual long wires which comprise the VEE antenna. It depends only on the radiating frequency and on the length in meters of the long wires.

Radiation Resistance (Ohms)

This output is the radiation resistance (i.e., the real part of the impedance) that would be seen by a transmission line connected to the antenna's input terminals.

3.2.20 Yagi-Uda

Yagi-Uda antennas are popular HF, VHF and UHF antennas. They provide a directional radiation pattern with a relatively narrow bandwidth. The antenna consists of a number of dipole elements arranged parallel to one another and in a single plane. Only one of these elements, the feed element, is directly excited via a connection to a transmission line carrying the incoming signal. The others are parasitic elements which are excited by the near fields radiated by the feed element. The feed element, which is the second element from the rear of the array, is resonant at the excitation frequency (i.e., its length is slightly less than half a wavelength). Because the feed element is in close proximity to the other elements, the tuned-nature of the antenna causes it to have a narrow bandwidth. The rear element acts as a reflector, sending energy back toward the feed element. The elements in the front of the antenna are slightly shorter than the feed element. These elements are called directors because they tend to focus the energy into a directional beam.

The method of moments technique is used to model the performance of the Yagi-Uda antenna. This technique yields the radiation pattern and the impedance of the Yagi-Uda antenna.

The Yagi-Uda Antenna Window is shown in Figure 3.2-21. Brief descriptions of the input and output parameters required for the Yagi-Uda antenna analysis are listed in the following subsections.

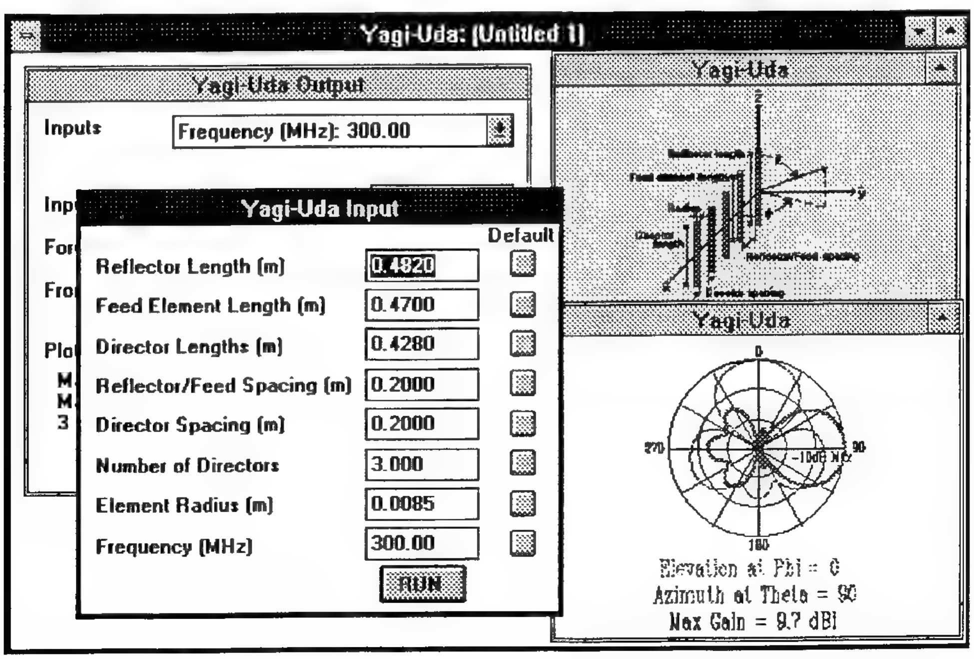


Figure 3.2-21. The Yagi-Uda Antenna Window.

3.2.20.1 Input Parameters

Reflector Length (m)

This input is the length in meters of the reflector which is the rear element in the array. This parasitic element tends to reflect energy radiated by the feed (or driven) element back towards the front of the array. Typically, the reflector is slightly longer than the driven element.

Feed Element length (m)

The feed (or driven) element is the second element from the rear of the array and is directly excited by the incoming wave. This element should therefore be resonant at the excitation frequency (i.e. slightly shorter than half a wavelength).

Director Lengths (m)

All of the elements from the front Yagi-Uda array to the third element from the rear of the array are the directors. If a Yagi-Uda antenna has 5 elements, for example, the 3 elements in the front will be the directors. Like the reflector, the directors are parasitic elements that derive their energy from the fields radiated by the driven element. Directors are typically slightly shorter than the driven element. These elements tend to focus the energy towards the front of the array thus forming a directional radiation pattern.

Reflector/Feed Spacing (m)

This input is the distance from the feed element to the reflector. The reflector is the rear element of the Yagi-Uda array.

Director Spacing (m)

This input is the distance between the directors and the distance from the feed element to the nearest director.

Number of Directors

This input is the number of directors that comprise the Yagi-Uda array. The directors are the elements from the front of the antenna to the driven element. In a 5 element Yagi-Uda antenna, for example, there will be 3 directors. Note that although the antenna image shows only 3 directors, you may model a yagi-uda with more (or less) elements. The antenna image, however, may not necessarily reflect your input model.

Element Radius (m)

The Yagi-Uda antenna is made up of an array of thin wire dipole antennas. This is the radius of the dipoles that comprise the array.

3.2.20.2 Output Parameters

Input Impedance (Ohms)

This output is the driving-point impedance of the antenna as seen by the amplifier.

Forward Gain (dBi)

This output is the peak gain produce by the antenna.

Front to Back Ratio (dBi)

This output is the ratio of the antenna's gain in the front of the antenna (i.e., along the positive X-axis) to the antenna's gain behind the antenna (i.e., along the negative X-axis).

4 NUMERICAL ELECTROMAGNETIC CODE MODULE (EAM-NEC)

The Numerical Electromagnetic Code module provides the capability for complete wire antenna analysis using a graphical user interface (GUI) which encompasses the Numerical Electromagnetic Code (NEC). The GUI includes a 3D antenna definition window to help the user visualize the model, error checking, and user-friendly dialog boxes to accurately specify NEC control parameters. Also included is the capability to rapidly display polar radiation patterns and colored current intensity diagrams.

Section 4 is divided into seven subsections. The first subsection is an overview of EAM-NEC from antenna definition through NEC execution to displaying the results. Subsection 4.2 discusses the menu bar which provides the major interface to storage devices, printing, execution of NEC, selecting output desired, screen management and access to the help system. Subsection 4.3 provides a detailed discussion of the antenna definition window. Subsection 4.4 discusses the tool bar and all the features provided by each tool buttons. Subsection 4.5 describes the functions and commands that can be activated using the keyboard and mouse. Subsection 4.6 provides a tutorial for the inexperienced user. The last subsection, 4.7, provides a discussion on features which were not implemented in EAM-NEC due to a combination of fiscal and schedule constraints.

4.1 EAM-NEC OVERVIEW

As seen in Figure 4.1-1, the Fine-Grain Radiator module consists of a menu bar, tool bar, drawing window, and model statistics. The menu bar on the module's main window allows access to file management operations, executes NEC, displays output plots, manipulates windows, and accesses help. The File menu item allows a user to open one or more antenna definition/drawing windows. These windows read numerical data stored in NEC input files and display the data as 3D images. Creating, viewing, editing, and printing antenna models is easily performed. The Run menu item is used to execute NEC in a manner that is transparent to the user. During NEC execution, a rotating wheel is displayed to signify that an analysis is being performed, Output plotting capability is provided via the Plot

menu item. Both polar radiation plots and current intensity diagrams are available. The Window menu item provides conventional window manipulation functions such as Cascade, Tile, Arrange Icons, and Close All Windows. The Help menu item provides assistance for using SAIC's graphical shell.

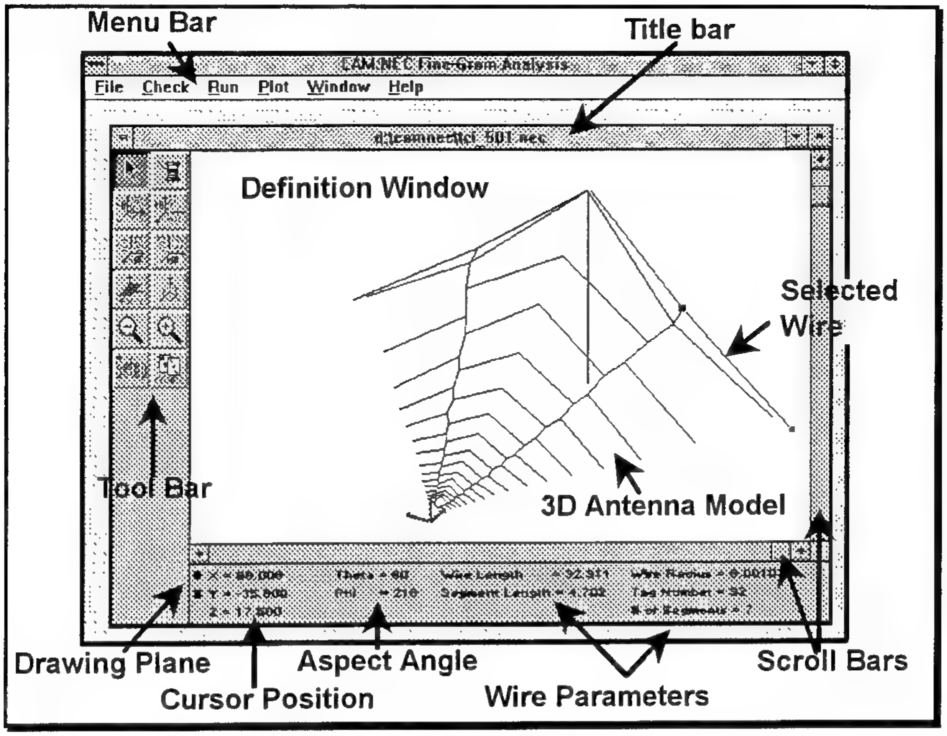


Figure 4.1-1 Graphical Shell with an Antenna Definition Window Open

4.1.1 Antenna Definition Window

A key feature of the Fine-Grain radiator module is the antenna definition window. The window was designed to have the look and feel of a typical Windows™ vector-based drawing package with additional features for drawing in 3D. This 3D drawing package automates the tedious work of defining and typing wire coordinates in a DOS text file by provide full 3D mouse movement. As shown in Figure 4.1-1, the antenna drawing window contains a window title, drawing area, wire and view manipulation tools, scroll bars, and drawing information.

A major advantage of using SAIC's graphical shell is wire definition. Defining a wire using SAIC's antenna definition window is similar to drawing a line in a typical drawing packages. Wires are drawn simply by clicking the left-mouse button, then "rubber banding" the wire to the wire end coordinate, and releasing the mouse button. The wire is displayed on the screen and its end-point coordinates are stored in memory for subsequent creation of a NEC input file. An existing wire

can be edited by using the arrow tool to stretch or shrink the wire from either of its ends in a similar fashion. Connecting two wires requires that the connecting ends have identical 3D floating point coordinate values. This is not easily accomplished when converting mouse cursor locations to 3D coordinates since the distance between screen pixels is often much larger than the resolution of a floating point number. SAIC's antenna drawing window provides three features to ensure precise wire connections: Snap-to-Grid, Wire-Segment Find, Wire-End Find, and Display segmentation. Snap-to-grid restricts the cursor movement to a user-defined 3D grid resolution. Wire-Segment Find, activated with the *"F"* key, sets the 3D cursor coordinates to that of the closest wire segment. Wire-End Find, activated with the *"Shift F"* keys, sets the 3D cursor coordinates to that of the closest wire end. Displaying wire segments is accomplished on a selected wire by depressing the *"S"* key, or for the entire model by depressing the *"Shift S"* keys..

To view antenna models in 3D space the model must be able to be viewed from any spherical coordinate (ρ,θ,ϕ). This is accomplished using scroll bars, zoom buttons, and orientation buttons. Scroll bars are used to change the location of the 3D origin on the screen. Zoom buttons allow a user enlarge a portion of a model to show more detail, or shrink the display to show more area. Coordinate system orientation buttons allow a user to view a model from any aspect angle (θ, ϕ). Each time a button is pressed, θ or ϕ is incremented or decremented by a user-defined amount.

After completion of the model's geometry, the model's control lines, excitation, frequency, and desired output need to be specified. SAIC's graphical shell includes a control line editor that simplifies specification of NEC's control and system parameters. Nearly all NEC control lines are included in the editor. A miscellaneous line allows the use of control lines not recognized by the line editor, such as, upper medium, dielectric sheath, and print control. The miscellaneous line can be used by the experienced user for the creation of any line.

4.1.2 NEC Execution

NEC, the computational engine in EAM-NEC, is recognized as a gold-standard in Moment Method codes and is used for predicting the performance of antennas less than a few wavelengths in size. Its core computation is the current distribution on a segmented wire/patch model. Computational time is directly related to the electrical size and segmentation of the antenna model. NEC, like most text-based

engineering tools, is user unfriendly and requires extensive knowledge and experience to be used correctly and effectively.

Execution of NEC is accomplished by selecting the Run menu item. NEC will automatically create and save an input file for the active drawing window, and then execute NEC. Once an analysis has begun, the cursor changes to a rotating wheel, signifying execution is in process. At this time, the user can take advantage of Windows' multi-tasking abilities and switch to another Windows™ application. SAIC's NEC graphical shell will run both an unmodified NEC-2 FORTRAN from the NEEDS package and NEC-3i compiled for a personal computer running DOS.

4.1.3 Output Processing and Displays

The graphical shell reads the NEC-generated files for desired information and plots the data in the form of polar radiation plots and color-coded current intensity diagrams. The graphical shell can graphically display data obtained from existing NEC output files as well as output files generated on a main-frame computer. Huge NEC models can be created with the graphical shell, transferred to a main frame computer for fast execution, and then the output file can be transferred back to the PC for graphical display.

Figure 4.1-2 displays the graphical shell's polar radiation plots. Both elevation and azimuth patterns can be displayed alone or simultaneously on a single polar plot. The two patterns are distinguished by both line color and type. The elevation pattern is a solid red line while the azimuth pattern is a dashed blue line. Selection of a specific ϕ (θ) angle for the elevation (azimuth) pattern is performed from the Plot-Options menu item.

Color-coded current intensity diagrams graphically display NEC's output current intensities superimposed with color on the model's geometry, shown in Figure 4.1-2. Red (hot) is used for segments with the highest current, while blue (cold) indicates low current. The value associated with each color can be determined automatically or can be defined by the user. Also included on these plots are frequency and input impedance.

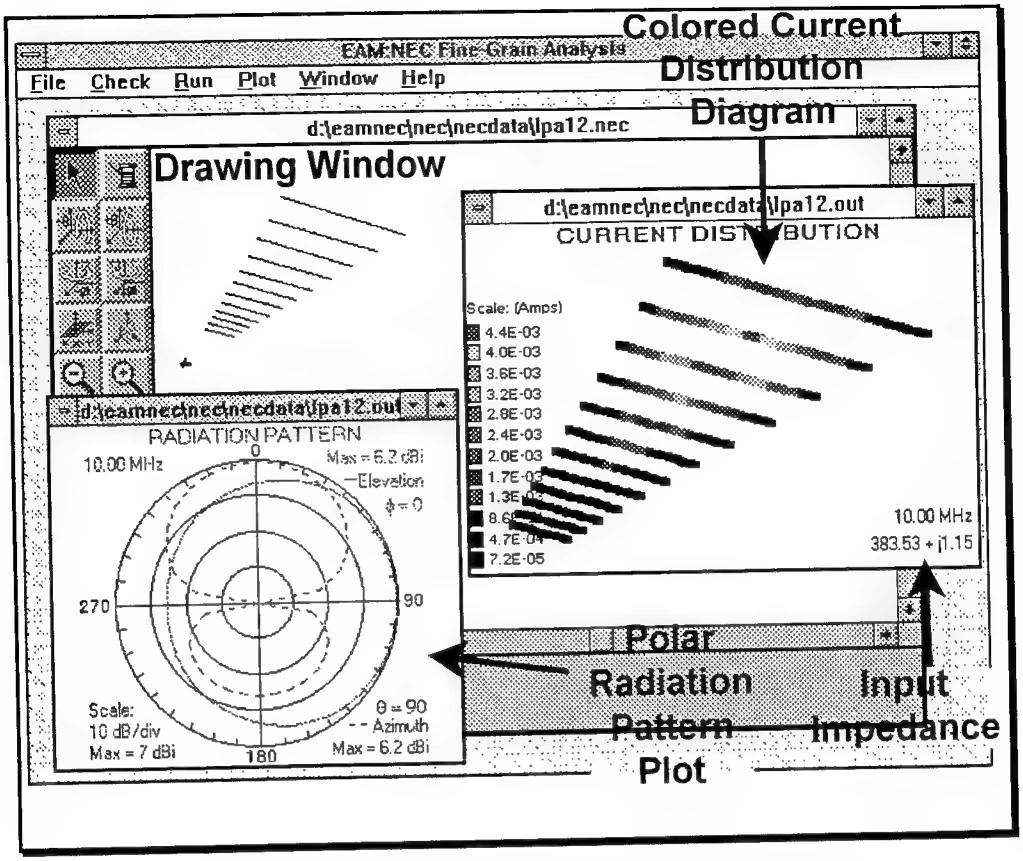


Figure 4.1-2 Multiple Windows Showing Model Geometry and Outputs

4.2 EAM-NEC MENU BAR

The EAM-NEC Menu Bar is located near the top of the application window, just below the Title Bar, as shown in Figure 4.2-1. The menu's top-level selections, which include **File**, **Run**, **Plot**, **Window**, and **Help,** allow you to access files, run an analysis, plot output data, select plot options, configure the windows on the screen, and activate the help system. The following sections describe each of the menu items.

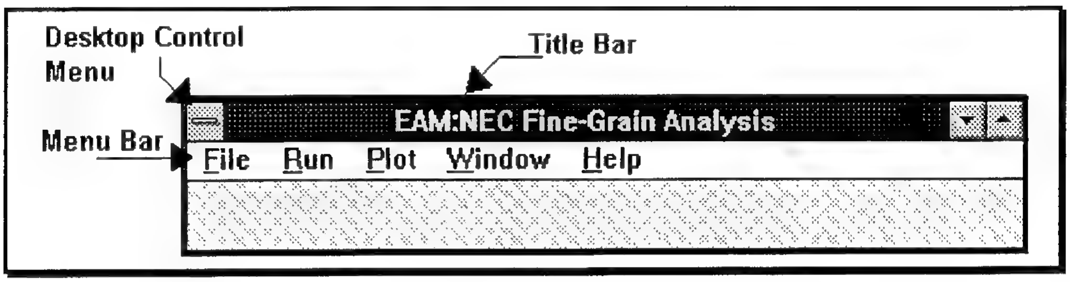


Figure 4.2-1. The EAM-NEC Main Menu Bar

4.2.1 File Menu

The **File** menu allows you to open, save, and print new and existing models. These features are accessed via sub-menu items: **New**, **Open**, **Open As Text**, **Save**, **Save As**, **Print**, **Print Setup**, and **Exit**.

New

The **File|New** menu item is used to open a new Antenna Definition Window. The window is created with a blank drawing area containing the XYZ axes and preset default drawing options.

Open

The **File|Open** menu item is used to open an existing NEC input file. Upon selection of **File|Open**, EAM-NEC provides a dialog box for specification of a path and filename. The default file extension that EAM-NEC searches for is '.nec', however, the user may alter this. After selecting a valid file, the corresponding model will be displayed graphically and all control lines will be listed in the Control Line Editor.

Open As Text

The **File|Open As Text** menu item is used to open an existing ASCII text file. Upon selection of **File|Open As Text**, EAM-NEC provides a dialog box for specification of a path and filename. The specified file will be opened and displayed as text in a text editor window. This a generic text editor that can make and save changes to a file.

Note: presently, the maximum file size that the text editor can read in is approximately 30 KB. Larger files can be opened and viewed, however, they will be truncated. If a file larger than 30 KB is opened and saved, the truncated information will be lost.

Save

The **File|Save** menu item allows the user to save the model in the active Antenna Definition Window (Drawing Window) to a file. **File|Save** uses a previously defined file name if one exists, otherwise it prompts you for a new file name. All models are saved in NEC input format. It is recommended that all EAM-NEC models use '.nec' for the filename's extension.

If the active window is the text editor window, File|Save will save in ASCII format.

Because NEC output data is automatically saved to a file, plots of the output data can not be saved. The output file data remains unchanged regardless of how many times you plot it.

Save As

The **File|Save As** menu item allows the user to save the model in the active Antenna Definition Window (Drawing Window) to a new filename. All models are saved in NEC input format. Use this command to save an existing file with a new name. It is recommended that all EAM-NEC models use '.nec' for the filename's extension.

If the active window is the text editor window, File|Save As will create a new file and save in ASCII format.

Because NEC output data is automatically saved to a file, plots of the output data can not be saved. The output file data remains unchanged regardless of how many times you plot it.

Print

The **File|Print** menu item allows you to create hard copy outputs of the screen using the default printer. These outputs are provided as a screen dump of the entire monitor display. **File|Print** also allows you to specify the number of copies and scaling of the image. The **File|Print Setup** menu item allows you to change the parameter settings of the default printer. Use the Program Manager's Control Panel to activate a different printer as the default printer.

Note: If the EAM-NEC window is maximized, a scaling selection of 140% will completely fill an 8 1/2x11 sheet of paper.

Exit

The **File|Exit** menu item allows you to close the EAM-NEC application. You will be prompted to save any newly created or modified models upon selection of this menu item.

4.2.2 Run Menu

The Run menu allows you to initiate analysis of the active model using NEC. EAM-NEC will spawn NEC and pass it the input and output file names. The output file name is always the same as the input file name (the active Antenna Definition Window with a '.out' file extension. Caution, if the output file name already exists, the existing data will automatically be replaced with new data.

While the analysis is running, EAM-NEC will be in an idle state and will display a running cursor. You are free to switch to another application while the analysis is active. EAM-NEC will notify you with a beep when the analysis is through.

Note: The model is automatically saved immediately prior to each execution of an analysis. This means that if you have made changes to an input model and run the analysis, the originally saved model will be overwritten. If the model has never been saved, you will be notified and the File|Save As dialog box will be brought up.

4.2.3 Plot Menu

The **Plot** menu allows you to graphically display radiation and current intensity data contained in NEC output files. The files need only to be in the typical NEC output format and do not have to be created using EAM-NEC, i.e., output files from other platforms running NEC may also be plotted.

With the **Plot** menu item, you have the capability to open multiple plot windows simultaneously. This allows for quick and easy comparisons of data from the same output file or from different files. In addition, certain plot options can be set from within this menu. All these features are accessed via the following sub-menu items: **Open|Radiation Pattern, Open|Current Intensity Diagram** and **Options**.

Open|Radiation Pattern and Open|Current Intensity Diagram

The **Plot|Open|Radiation Pattern** and **Plot|Open|Current Intensity Diagram** menu items allow you to select NEC data files for plotting the antenna's gain and the current intensity, respectively. Each menu item first brings up a ***File Open*** dialog box. In this dialog box, you specify the drive, directory, and filename of an existing NEC output file to be plotted. The default file extension that EAM-NEC searches for is '.out', however, you may alter this. In addition to specifying the data file, you can select the "Options" button located on the right side of the dialog box. The "Options" button will provide you with the same dialog box you would get by selecting the **Plot|Options** menu item.

After selecting a file, EAM-NEC automatically searches the file for the appropriate output data. If you are plotting a radiation pattern and no data is found, EAM-NEC notifies you that no radiation pattern data exists and then displays a blank plot. If you are plotting the current intensity and no data is found, EAM-NEC will display the current intensity diagram as all black, (Current = 0A).

Options

Selecting the **Plot|Options** menu item brings up a dialog box that allows you to specify parameters for the selected plot window. The dialog box displayed depends upon the data being plotted, i.e. a radiation pattern or a current intensity diagram. This menu item is available only when a plot window is active. The **Plot|Options** menu item and its dialog boxes are discussed in greater detail in Section 4.6.

4.2.4 Window Menu

The **Window** menu allows you to manipulate the display of open windows. Sub-menu items include: **Cascade**, **Tile**, **Arrange Icons**, and **Close All**.

Cascade

The **Window|Cascade** menu item re-sizes and layers all open windows. It automatically arranges the windows so that they are neatly stacked on the screen in an overlapping fashion, from left to right, top to bottom, with only the window title showing.

Tile

The **Window|Tile** menu item re-sizes and re-positions all open windows so that they are all visible on the screen concurrently. The windows are arranged so that they are as big as they can be without overlapping each other. This is a quick way to neatly display all windows.

Arrange Icons

Selection of **Window|Arrange Icons** causes all window icons to be neatly displayed along the bottom of the EAM-NEC application window. Icons are used to represent windows that are open but have been minimized by the user to reduce screen clutter.

Close All

The **Window|Close All** menu item automatically closes all EAM-NEC windows. You will be prompted to save files when necessary. Only windows are closed, the application remains active.

4.2.5 Help Menu

EAM-NEC includes a comprehensive, on-line help system. This help system can be accessed via the **Help** menu. The **Help** menu includes two sub-menus: **Index**, and **About EAM-NEC**.

Index

Selecting the **Help|Index** menu item causes EAM-NEC to activate the help system. The help system will display an index of available information for all the EAM-NEC menus and features. Topics highlighted in green indicate that additional information is available. This information can be accessed by simply pointing and clicking on the desired topic.

This command can also be activated with the "F1" function key.

About EAM-NEC

The **Help|About EAM-NEC** menu item brings up a dialog box to display the application version number, a copyright notice, and the serial number.

4.3. THE ANTENNA DEFINITION WINDOW

The Antenna Definition Window (ADW) is the focal point for drawing and defining the NEC input model. From within this window, you can use the mouse to draw the physical structure of the model, specify wire parameters, and define the program control lines. The window is divided up into three separate areas: the drawing area, the tool bar, and the information window (Info window). Each of these is pointed out in Figure 4.3-1.

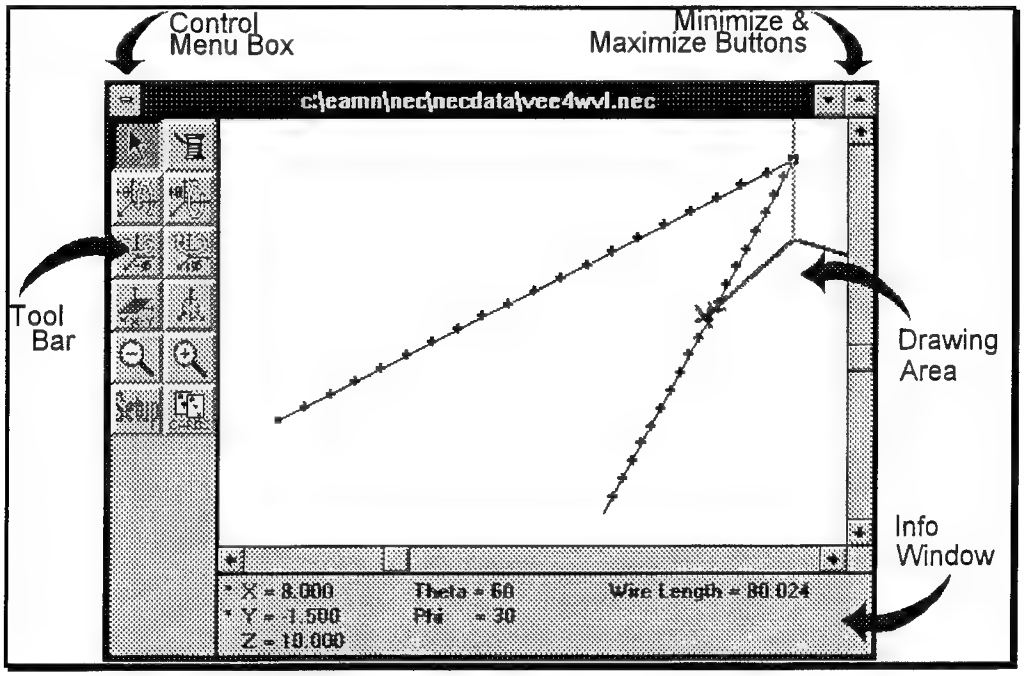


Figure 4.3-1. The Antenna Definition Window.

The ADW is used to completely define an input file. It is titled to indicate the file name and path, or in the case of a new and unsaved model, the ADW is labeled as ***untitled***. The ADW can be moved and re-sized within the EAM-NEC application window, creating a larger, or smaller, drawing area. The size and relative position of the tool bar and the Info window always stays the same. If the ADW is resized so that it is narrower or shorter than these windows, they will be truncated.

The Drawing Area displays all the physical features of the input model. The window always comes up with the three coordinate axes centered. The model's magnification and orientation can be varied from the Tool Bar, and its the drawing area can be moved left/right and up/down using the vertical and horizontal scroll bars. The resolution of the mouse movements while drawing within the Drawing Area, i.e. the snap-to-grid resolution, can be adjusted using the Set Up tool from the Tool Bar. Using Set Up, you can also change the maximum allowable dimension for the input model. Each of these features is discussed with more detail in the following sections.

Directly to the left of the Drawing Area is the Tool Bar. The Tool Bar contains all the available tools for drawing and defining a model and its parameters, as well as for manipulating the model view. The function each tool provides applies only in the ADW. The Tool Bar is discussed in greater detail in Section 4.4.

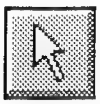
Located below the Drawing Area is the Info Window. As its name suggests, the Info Window contains information specific to the model. This includes, the XYZ location of the cursor, the Theta and Phi values for the viewing orientation, the drawing plane the cursor is moving in, and the length of the wire. As you can see in Figure 4.3-1, the cursor location is indicated in the left side of the Info Window. Along side two of the labels, in this case X and Y, there are asterisks. These two asterisks represent the drawing plane (the plane the mouse is in), which in this case, is the XY-plane. These asterisks are automatically updated whenever the drawing plane is changed. If the viewing orientation of the model is changed so that the drawing plane is no longer visible (the plane looks like a line), the cursor will act as if it is frozen. This can be quickly remedied by changing the drawing plane.

4.4. THE TOOL BAR

The tool bar is located on the left side of the Antenna Definition Window (ADW). It contains all the available tools for drawing and defining a model and its parameters, as well as for manipulating the model view. The function each tool provides applies only in the ADW.

The following sections will describe each tool individually.

4.4.1 The Arrow Tool



This is the default tool for model construction in EAM-NEC. Selecting "Arrow Tool" button will change the cursor to an arrow and will activate the arrow tool functions. There are several functions associated with the arrow tool when operating in the Antenna Definition Window. These include:

Selecting a Wire

Models are built by drawing lines that represent wires. With the arrow tool, you can select and activate any of the model's wires. This can be accomplished simply by clicking the mouse on, or in close proximity to, a wire. Once a wire is selected, it is highlighted with small black square markers at its ends. In order to easily differentiate the two ends, the marker on end one (beginning) is larger than the marker on end two (end).

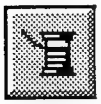
Stretching a Wire

When a wire is selected, the arrow tool can be used to change the location of its ends, thereby stretching or shrinking it. To modify a wire, simply select the end that is to be moved and, while holding the left mouse button down, drag it to a new location. The wire's parameters are automatically updated to include the new location coordinates.

Activating the Wire Parameters Dialog Box

Using the arrow tool, it is possible to activate and display a dialog box that allows you to view and edit a wire's parameters, i.e. the radius, number of segments, tag number, and end point coordinates. This can be accomplished in a fashion similar to selecting a wire, however, this time the mouse must be double-clicked. Double-clicking on or close to the wire will automatically select the wire and bring up its parameters dialog box.

4.4.2 The Wire Tool



Selecting the "Wire Tool" button activates the wire drawing tool and changes the ADW cursor to a wire spool cursor. This cursor signifies that you are in the wire drawing mode. All parameters for a new wire, geometric as well as non-geometric, are defined in this mode.

Wire Default Parameters

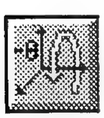
Each new wire is given default values for specific parameters, including radius, tag number, and number of segments. These default values can be displayed and modified by double-clicking on the "Wire Tool" button. This action brings up a ***Wire Tool Defaults*** dialog box which can be edited. After the parameters in this dialog box are edited, each new wire drawn will be assigned the new values.

Wire Coordinates

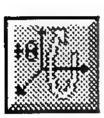
In NEC, a wire is defined by location of its ends relative to the coordinate system origin. In the wire drawing mode, the mouse is used to define the coordinates of the ends. The first wire end is specified by simply clicking the mouse at the desired coordinates. The other end is similarly specified by moving the mouse in the drawing area of the ADW and clicking at the new location. The new coordinates, combined with the parameters specified via the *Wire Tool Defaults* dialog box, completely define a wire.

4.4.3 The Rotate Theta (θ) Tool

Theta is measured as the angle between the positive Z-axis and a line drawn perpendicular to the screen from the origin.



Selecting this button will rotate the entire model so that theta is decremented. The curved arrow shows the apparent rotation of the model.



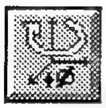
Selecting this button will rotate the entire model so that theta is incremented. The curved arrow shows the apparent rotation of the model.

The delta for rotation in theta can be customized by selecting the "Set Up Tool" button (the default is 15 degrees).

4.4.4 The Rotate Phi (ϕ) Tool

Phi is measured as the angle between the positive X-axis and the projection in the Z=0 plane of a line drawn perpendicular to the screen from the origin. Phi is always measured in the positive Y direction.

Selecting this button will rotate the entire model so that phi is decremented. The curved arrow shows the apparent rotation of the model.



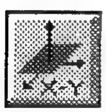
This button will rotate the entire model so that phi is incremented. The curved arrow shows the apparent rotation of the model.

The delta for rotation in phi can be customized by selecting the "Set Up Tool" button (the default is 15 degrees).

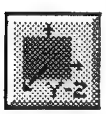
4.4.5 The Rotate Plane of View Tool

Standard Plane Configurations

There are three functions and faces associated with this one button, as shown below.



X-Y Rotate the model so that the user's view is normal to the XY-plane (θ=0, ϕ=0).

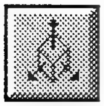


Y-Z Rotate the model so that the user's view is normal to the YZ-plane. (θ=90, ϕ=0)

Z-X Rotate the model so that the user's view is normal to the ZX-plane (θ=90, ϕ=90).

These functions are all part of a rotation that advances each time the button is selected. With each button click, the next function, and tool button face representative of the function, is called. For example, the first time the button is pressed, the model will be rotated to the XY-plane. If the button is pressed again, the model will be rotated to the YZ-plane. One more press will rotate the model to the ZX-plane, and another back to the XY-plane. This rotation sequence always begins in the XY-plane.

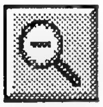
Isometric View



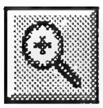
This button will rotate the model so that it is viewed from an isometric perspective (θ=45, ϕ=45).

4.4.6 The Zoom-Out and Zoom-In Tools

These tools vary the magnification of the drawing area in the ADW.

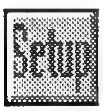


Reduces the magnification of the drawing area.



Increases the magnification of the drawing area.

4.4.7 The Set Up Tool



This button allows you to customize several settings for drawing in the ADW. The available options are listed below.

Max Model Dimension

This value controls the maximum model coordinate that can be specified. For new models, it is suggested that you specify a number approximately 20% larger than the maximum desired coordinate location. For existing models, this option is automatically set at 25% beyond the largest coordinate location. This setting is primarily to allow for a reasonably sized drawing area to be created.

Grid Resolution (Grid spacing)

This value controls the snap-to-grid resolution. For new models, it is easiest to draw when the maximum grid resolution is used, i.e. use a course resolution for the basic framework and then a finer grid resolution for detailed work. For example, if a model is to be created in 0.5 meter increments, the grid resolution should be set to 0.5. A setting of anything less would be unnecessary, and could even create a more difficult environment to work in.

Aspect Angles

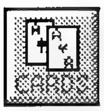
Theta Set Theta to a specific angle.

Phi Set Phi to a specific angle.

Theta Increment Set the increment associated with the "Rotate Theta" tool buttons.

Phi Increment Set the increment associated with the "Rotate Phi" tool buttons.

4.4.8 The Control Line Editor Tool



Selecting the "Cards Tool" button activates the control line editor. The editor is custom designed to help simplify the specification of a model's control lines, i.e. excitation, frequency, output, etc. It provides the capability to add new lines, delete old lines, modify the contents and order of existing lines, and even to create a default list to be used with other models. Figure 4.4-1 shows the control line editor with all its options.

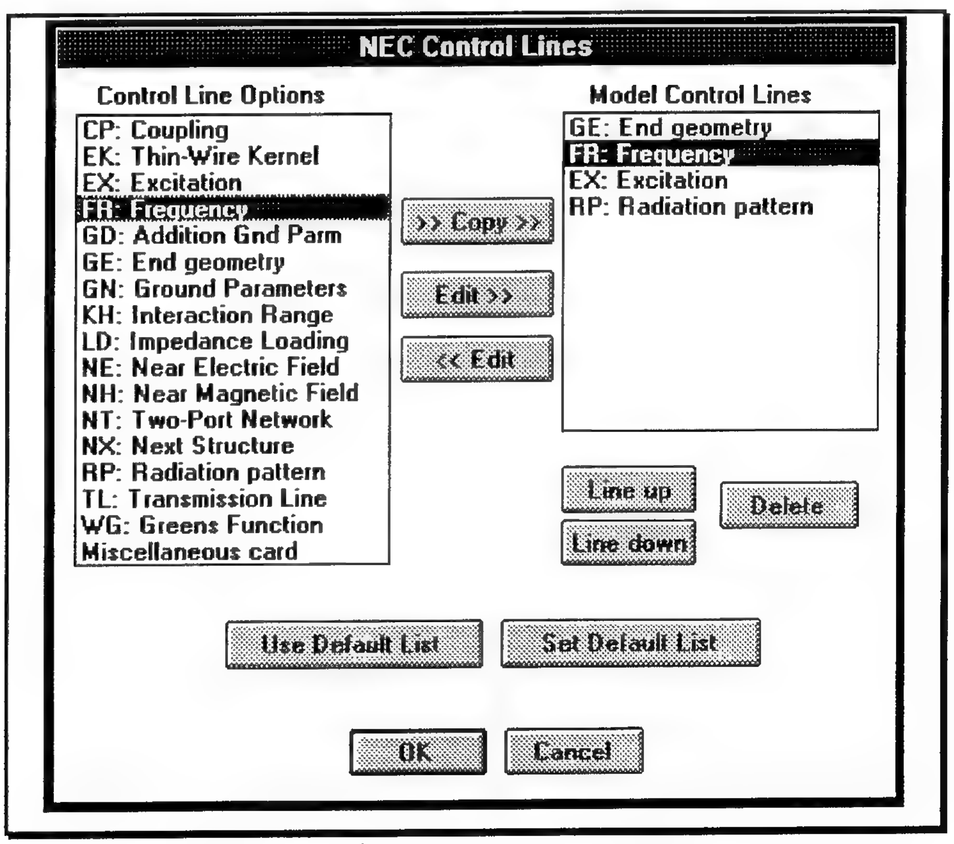


Figure 4.4-1. The Control Line Editor

Editor Parameters

Control Line Options This is a list of the control lines available for use with the model (shown on left of editor).

Model Control Lines This is a list of the control lines selected for this model (shown on right of editor). Figure 4.4-1 shows four control lines used to specify the end of the geometry definition, to define the frequency and type of excitation, and to compute a specified radiation pattern.

Editor Options

>> Copy >> Select ">>Copy>>" to duplicate a control line from the Control Line Options list to the Model Control Lines list. The copied card will retain all the settings of the original card.

Edit >> Select "Edit>>" to view and edit a control line's parameters from the Model Control Lines list.

<< Edit Select "<<Edit" to view and edit the default values for a control line from the Control Line Options list. The new values will be stored and will be available to other models. New values are retained only when the Control Line Editor OK button is selected.

Line Up Select "Line Up" to move the position of a highlighted control line forward in the Model Control Line list.

Line Down Select "Line Down" to move the position of a highlighted control line backward in the Model Control Line list.

Delete Select "Delete" to remove a control line from the Model Control Line list.

Use Default List Select "Use Default List" to clear the existing Model Control Line list and replaces it with a user defined default list.

Set Default List Select "Set Default List" to store the existing Model Control Line list as the Default List. The default list can then be recalled with the "Use Default List" button.

OK Select "OK" to close the Control Line Editor and save all the changes made while it was open.

Cancel Select "Cancel" to close the Control Line Editor and discard all the changes made while it was open. This includes changes made to the default list.

Note: For information regarding control line specifications and model requirements, please consult with the NEC User's Manual.

4.5 KEYBOARD AND MOUSE COMMANDS

This section will describe various functions and commands that can be activated using the keyboard and mouse.

4.5.1 Moving the Cursor with the Keyboard

In addition to the mouse, the keyboard can be used to move the drawing cursor within the Antenna Definition Window. The keyboard commands can be used for movement in all directions, or, when used together with the mouse, it can be used to restrict movement to a single direction. Below is a list of keystrokes and their function.

Key(s)	Function
X (Ctrl X)	Moves the cursor in the positive (negative) X direction. Each keystroke increments (decrements) the cursor position by 1 grid spacing. Grid spacing can be customized with the Set Up Tool.
Y (Ctrl Y)	Moves the cursor in the positive (negative) Y direction. Each keystroke increments (decrements) the cursor position by 1 grid spacing. Grid spacing can be customized with the Set Up Tool.
Z (Ctrl Z)	Moves the cursor in the positive (negative) Z direction. Each keystroke increments (decrements) the cursor position by 1 grid spacing. Grid spacing can be customized with the Set Up Tool.
H or Home	Both of these keys will move the cursor to the coordinate axes origin.
Shift	Shift restricts the movement of the cursor to a single plane. For example, if the XY-plane is selected and shift is pressed, moving the mouse in the drawing area will vary the cursor location only in the ±X direction. Shift + YZ-plane allows cursor location to vary only in ±Y, and Shift + ZX-plane only in ±Z. **Shift** applies to cursor movement via keystrokes as well as the mouse.

4.5.2 Drawing Assistance with the Keyboard

A few simple keyboard stokes assists in insuring the antenna model is a electrically correct. For compatibility with NEC, all electrical connecting must be made at segment connections. The following keystrokes simplify this procedure.

Key(s)	Function
S	Toggles the segment display the selected wire.
Ctrl S	Toggles the segment display the entire model.
F	Moves the cursor to the nearest segment end
Ctrl F	Moves the cursor to the nearest wire end.

4.5.3 Deleting Wires with the Keyboard

Two steps are required to delete a wire from a model:

1. With the mouse, select the "Arrow Tool" from the Tool Bar. Using the "Arrow Tool", select the wire to be deleted.

2. Press the ***Backspace*** or ***Delete*** key to remove the wire.

Note: it is not possible to undelete a wire.

4.5.4 Keyboard Commands in a Dialog Box

The following keyboard commands can be used to manipulate data within a dialog box. Using these commands, you can perform the same actions as with the mouse.

Tab	Serially moves input focus through each field in a dialog box.
Shift+Tab	Serially moves input focus through each in reverse order.
Alt+letter	Moves input focus to the field or group whose underlined letter matches the one typed.
Arrow key	Moves input focus through each field within a group of options.
Enter	Executes the active button (the button with a bold border around it).

Esc	Closes a dialog box without completing the command. (Same as Cancel)
Alt+Down Arrow	Opens a drop-down list box.
Alt+Up or Down Arrow	Selects item in a drop-down list box.
Spacebar	Cancels a selection in a list box.
Ctrl+/	Selects all the items in a list box.
Ctrl+\	Cancels all selections except the current one.
Shift+ Arrow key	Extends selection in a text box.
Shift+ Home	Extends selection to first character in a text box.
Shift+ End	Extends selection to last character in a text box

4.5.5 Mouse Commands in the Tool Bar

Left Mouse Button

Single-Click A single-click activates the tool or function that is selected.

Double-Click Presently, a double-click in the tool bar affects only one of the available tools, the "Wire Tool". Double-clicking the "Wire Tool" button activates the ***Wire Tool Defaults*** dialog box.

Right Mouse Button

The right mouse button has no function in the tool bar.

4.5.6 Mouse Commands in the Antenna Definition Window

Left Mouse Button

The left mouse button is used to draw, select, and edit wires. Its exact function can vary and is dependent on the tool that is selected. For instance, with the "Arrow Tool" selected, the left mouse button can be used to either stretch or select a wire. With the "Wire Tool", the left button is used to draw a new wire.

Right Mouse Button

The right mouse button provides the user with the ability to switch drawing planes without ever leaving the Antenna Definition Window, and thus, without interrupting the definition of a wire.

Clicking the right mouse button changes the plane of motion from the XY-plane to the YZ-plane, from the YZ-plane to the ZX-plane, and from the ZX-plane back to the XY-plane. The drawing plane is indicated in the left side of the Info Window with asterisks next to the two letters of the drawing plane.

4.6 EAM-NEC TUTORIAL

This section will present a detailed step-by-step tutorial of the major features of EAM-NEC. This will be done by modeling a typical antenna problem. The problem is as follows:

1. Predict a dipole's performance with these dimensions, l = 0.5m, r = 0.001m and frequency, 300 MHz,

2. Display the dipole's far field radiation pattern, and

3. Display the current distribution across the dipole.

4.6.1 Open an Antenna Definition Window

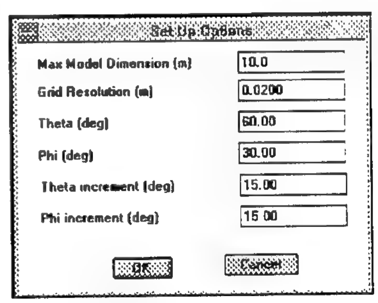
This section discusses opening a Antenna Definition Window (ADW) to create a new, or edit an existing, NEC input file

Creating a New Input File

To create a new input file, select the **File|New** command from the main menu. This will bring up a new ADW for creating an input model. The ADW contains all the available tools for creating a new model. With EAM-NEC, you also have the capability to open multiple ADWs simultaneously.

Setting up the New ADW

Open the Setup Dialog Box by clicking in the "setup" button. Adjust the grid resolution from the default value 0.5m to 0.02m. Selecting "OK" will close the dialog box and save the new values.



4.6.2 Creating and Editing Wires

This section discusses how to set up the "Wire Tool" defaults for drawing multiple wires with identical parameters, how to draw a new wire, and how to edit an existing wire.

Creating a New Wire

Setting Default Wire Parameters

Upon opening a ADW, the default parameters for all new wires are set for a 0.0010 radius, 5 segments, and a tag number of 1. . If desired, new default parameters can be specified via the ***Wire Tool Defaults*** dialog box before drawing the wire. This dialog box is activated by double clicking on the "Wire Tool" button. Excluding the wire end coordinates, it contains all the information required to fully define a wire. This includes radius, segments, and tag number. Any changes made in the ***Wire Tool Defaults*** dialog box will apply to all new wires created during that session. Changes made will not apply to any existing wires or other ADWs. These parameters can also be changed after drawing but not in a global fashion.

Drawing a Wire Which Represents the Dipole

New wire end coordinates are specified using the Wire Tool. The wire can be drawn in any plane using the mouse with or without the keyboard. Location is changed simply by moving the mouse around in the drawing area, the drawing plane is switched with the right mouse button, and each new corner is defined with a left mouse button click. When used all together, these three techniques will define a wire.

Example

Define a wire with a radius of 0.001 m, 11 segments, tag number of 1, and with the coordinates (0,-0.25,0) and (0,0.25,0). This wire is pictured in Figure 4.6-1.

Step 1: Double-click on the "Wire Tool" button to bring up the ***Wire Tool Defaults*** dialog box. Define the wire's default parameters by entering a 1 for *Tag Number*, a 11 for *# of segments*, and a 0.001 for *Radius*. Select "OK" to save the settings. This only needs to be done once for these settings to apply to all new wires.

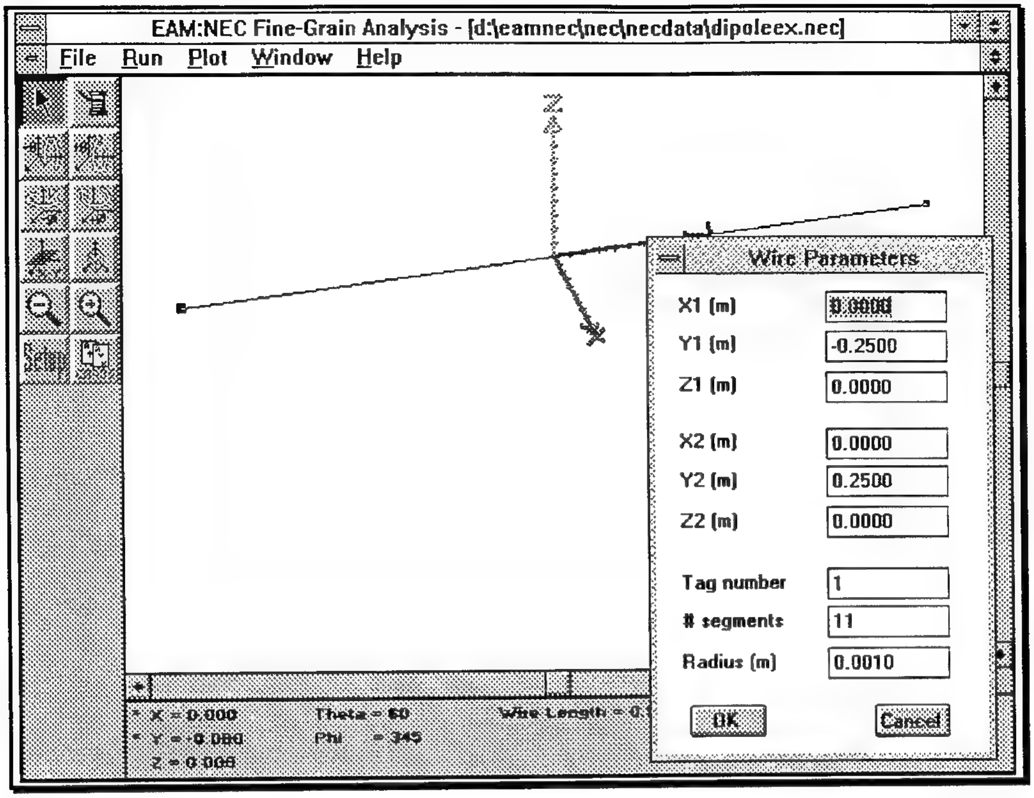


Figure 4.6-1 Dipole Antenna with Wire Parameter Box Open

Step 2: Hit the "H" or "Home" key to place the cursor at the coordinate system origin. Click the right mouse button to rotate the drawing plane (the plane the mouse moves in) to either the XY-plane or the YZ-plane. This will allow for movement in the Y direction. The asterisks next to the coordinate labels in the Info window indicate the drawing plane.

Step 3: Move the cursor along the Y axis to X=0, Y=-0.25, Z=0. With the wire tool, define wire end one by clicking and holding down the left mouse button.

Step 4: Without releasing the left mouse button, move the cursor along the Y axis to X=0, Y=0.25, Z=0. The wire will appear with a black square on each end, the square on end one being the bigger of the two. Definition of the wire is now complete.

Hint: Holding the shift button down will restrict movement to only 1 dimension. For example, holding the shift button down when drawing in the YZ-plane will restrict movement to the Y direction. To draw only in Z, hold the shift button and click the right mouse button. The active direction is indicated in the Info Window with an asterisk next to the coordinate labels.

Editing an Existing Wire

Modifying the Parameters of an Existing Wire

The Arrow Tool is used to change the parameters of an existing wire. Double-clicking with the arrow tool on the specific wire will bring up that wire's ***Wire Parameters*** dialog box, shown in Figure 7-1. This dialog is essentially the same as the ***Wire Tool Defaults*** dialog except that it also contains the wire's end coordinates. Any changes made in the dialog box will apply only to that wire.

To edit any of the wire's parameters, simply place the cursor in the desired parameter edit box, delete the existing value, and enter the new value. All changes are saved only when the dialog's "OK" button is selected. Selecting "Cancel" will discard all changes and return to the drawing area retaining the original parameters.

Editing End Coordinates

Wire end coordinates can also be modified in the drawing area. Again using the arrow tool, the end is selected with the left mouse button. While holding the button down, the cursor can be dragged to the new location and then released. The coordinate change is automatically entered. The keyboard can also be used to enter a change by selecting a key, "X", "Y", or "Z", while the corner is selected with the mouse. Hitting the key moves the cursor just like moving the mouse.

Note: consult with the NEC User's Guide to get more details about the individual wire parameters.

4.6.3 Manipulating the Model View

Altering the Viewing Angle of the Drawing Area

There are six buttons in the tool bar used to rotate a model. Two buttons are used to rotate in Theta, two to rotate in Phi, and two to rotate the model to conventional views.

To look at the dipole model from the top, click on the "-θ" button. The arrow on the button face represents the apparent direction of the model rotation. The "+θ" button will move the model in the opposite direction. The "-ϕ" and "+ϕ" buttons also rotate the model except it is now rotated around the Z-axis. The θ and ϕ rotation increments in degrees can be modified via the "Set Up Tool" button. The resolution of rotation can be adjusted from 1 to 90 degrees.

To quickly bring the model to a plan view, click the "X-Y" button on the tool bar. This will automatically rotate the model so that you are viewing the XY-plane. Clicking the "X-Y" button again will rotate the model to the YZ-plane. Notice that the face of the button is now labeled as "Y-Z". Clicking the same button again will rotate the model to the ZX-plane and also change the face. One more click will return the model to the XY-plane. This button will always rotate the model in this sequence. You can also achieve an isometric view by clicking on the "Isometric" tool button. This will automatically rotate the model to $\theta=45$, $\phi=45$.

Varying the Magnification of the Drawing Area

Magnification of the drawing area is controlled with two buttons in the tool bar that look like magnifying glasses: Zoom Out(-) and Zoom In(+). Zoom Out decreases the magnification, allowing a greater area to be viewed. Zoom in increases magnification, providing a view with greater detail.

With dipole model at the center of the drawing window, click on the "Zoom In(+)" button. This will zoom you into the center of the drawing area. Naturally, clicking on the "Zoom Out(-)" button will reduce the magnification of the model in a similar fashion.

With dipole model anywhere in the drawing window, click on the wire to select it. Now click on the "Zoom In(+)" button. This will zoom you into the center of the selected wire.

Scrolling the Drawing Area

Using the scroll bars on the drawing window, the model position in the drawing area can be shifted left or right, and up or down. With an existing model open, click on the scroll bar arrows and notice how the model is shifted. Also, try clicking in the scroll bar itself. Notice that the shift is much more drastic.

4.6.4 Defining and Editing Model Control Lines

The Control Line Editor was designed to help make the specification of control line options more intuitive and simple for all users. The Control Line Editor is activated by clicking on the "Cards Tool" button. As shown in Figure 4.6-2, the dialog contains two list boxes entitled: Control Line Options and Model Control Lines. The Control Line Options list box lists all the available control lines and the Model Control Lines list box lists the control lines associated with the current antenna model.

Minimum Required Model Control Line

Each model requires the minimum of four control lines as follows:

1. Geometry End Line	(GE)
2. Excitation Line	(EX)
3. Frequency Line	(FR)
4. Execution Line	(XQ, RP, NE, NH, etc.)

An end line (EN) is also required, EAM adds that line automatically.

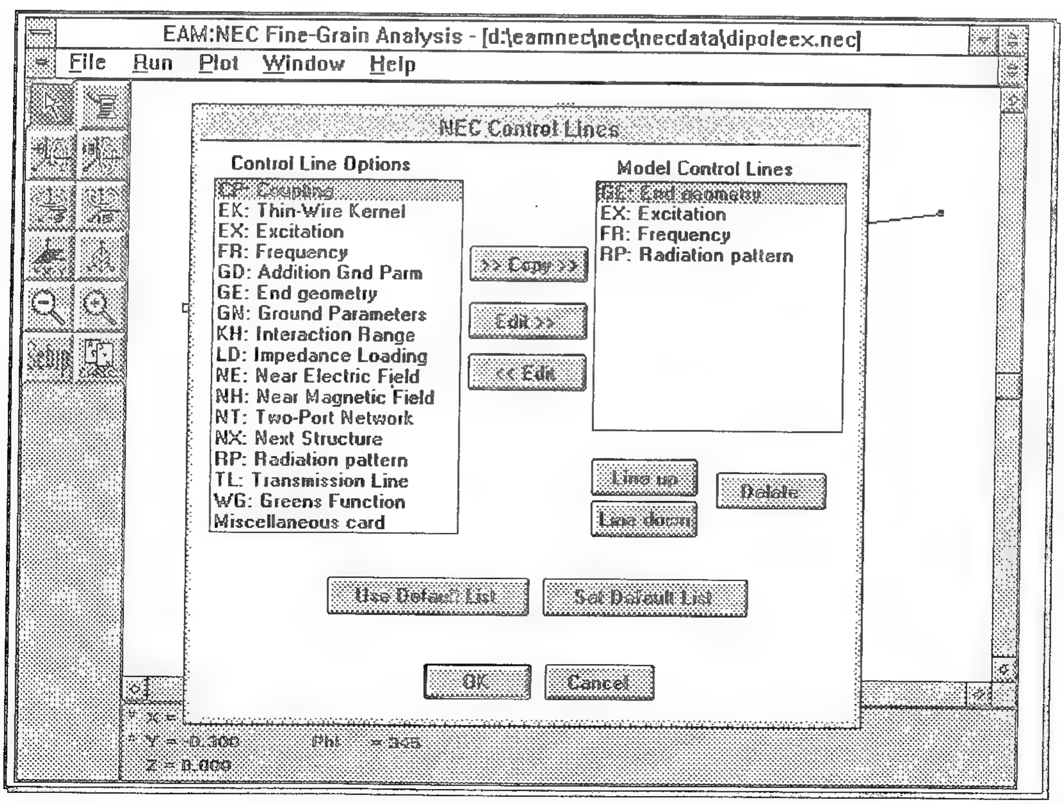


Figure 4.6-2 The Control Line Editor
Displaying the Model Control Lines

Creating a New Model Control Line List

Creating a new control line list is as easy as copying lines from the Control Line Options listbox to the Model Control Lines listbox. Each line must be added one at a time. To begin, select a **GE: End Geometry** from the Control Line Options listbox. Once a line has been selected, highlighted, selecting the ">>Copy>>" button will put a duplicate of that line into the Model Control Line listbox. Repeated this process for the **EX: Excitation**, **FR: Frequency**, and **RP: Radiation Pattern** lines.

Modifying an Existing Model Control Line List

There are five ways to modify a Model Control Line list: edit line options, add lines, move lines up or down in order, and delete lines. Each of these particular item are discussed under drawing tools. We need to edit each of the control line for our particular model.

Editing the GE Control Line:

The first step in editing a control line is to select the **GE: End Geometry** line from the Model Control Lines listbox. Once the line has been selected use the "Edit >>" button to bring up its options dialog box as shown in Figure 4.6-3. We need to select our antenna's environment, free space, we must select "No ground Plane". After the parameters have been specified, "OK" should be selected. This will retain any changes made to the line's parameters.

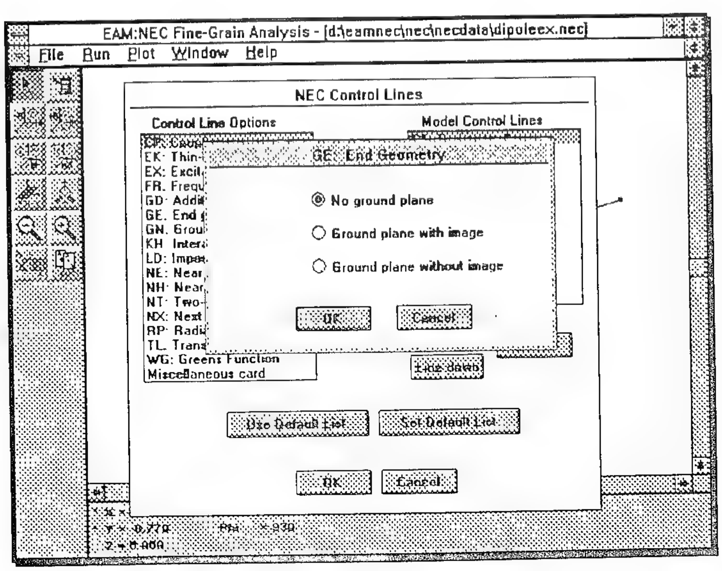


Figure 4.6-3 The End Geometry Dialog Box

Note: some control lines may not have any options to select and a beep is given to notify you that it cannot be edited.

Editing the EX Control Line:

The next step is to instruct NEC where to excite the model. This is done by editing the **EX: Excitation** Line as shown in Figure 4.6-4. The dipole wire is tag number 1 and has 11 segments, therefore the center segment is number 6. The excitation used is a 10 volt source placed on tag 1 segment 6.

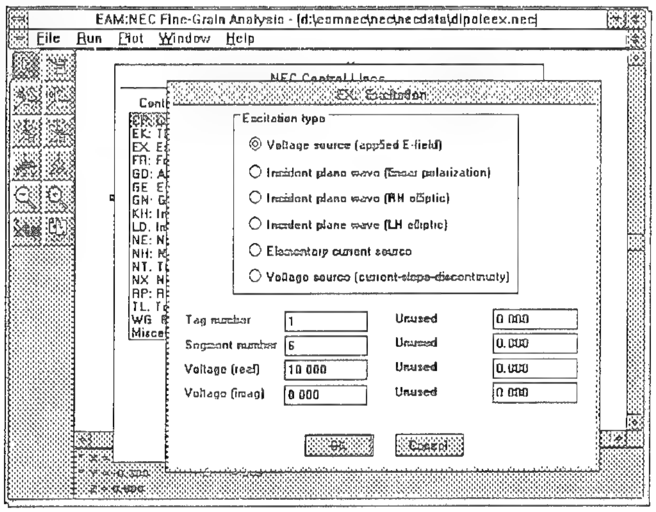


Figure 4.6-4 The Excitation Dialog Box

Editing the FR Control Line:

The next step is to instruct NEC what frequency to excite the model. at. This is done by editing the **FR: Frequency** Line as shown in Figure 4.6-5. We are only looking at 300 MHz but NEC allows the sweep of frequency.

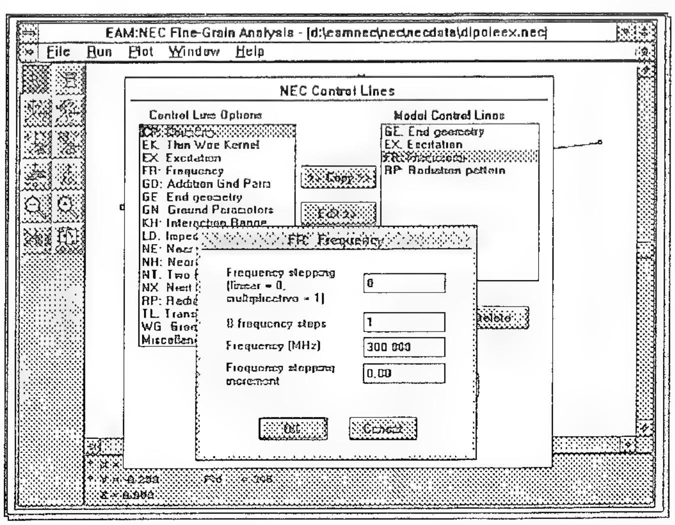


Figure 4.6-5 The Frequency Dialog Box

Editing the RP Control Line:

The last line to modify is the specification of the output desired. For our case we want a completed 3-D sphere of pattern data. Select the **RP: Radiation Pattern** line and select "edit>>". The dialog box shown in Figure 4.6-6 will appear and select "Complete 3-D Sphere". This instructs NEC to calculate the gain at 3° increments of θ and ϕ.

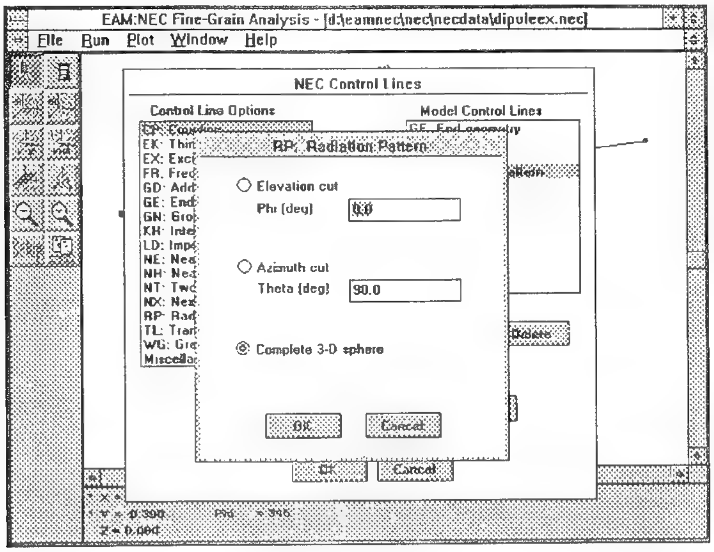


Figure 4.6-6 The Radiation Pattern Dialog Box

Closing the Control Line Editor:

Once all the lines are correct for the particular model, click on the "OK" button. This will close the control line editor and retain the control line list for attachment to the model geometry when the model is saved. These changes made to the control line list could have been made to the control line options list and would have become default parameters.

Modifying Control Line Options List Defaults

The procedure for modifying the default settings of lines from the Control Line Options listbox is similar to editing control lines from the Model Control Lines listbox. Again, the first step is to select the specific line to be edited. Once the line has been selected, use the "<< Edit" button to bring up its options dialog box. After the options have been specified, "OK" should be selected. This will retain any changes made to the line's options.

Note: Changes made in the Control Line Options listbox will be available for all models, new and existing.

Using a Default List of Control Lines

Many times, a user may have a generic list of control lines that is used as a base set for many models. With EAM-NEC, such a list can be saved as a default list to be used on future models. To save a default list, simply create the list in the Model Control Lines listbox and select the "Set Default List" button. To later implement the default list, select the "Use Default List" button. This will automatically delete all the lines in the Model Control Lines listbox and replace them with the default list. **Note**: Care should be taken when using this option because there is no command to "undo" the deletion of a model control line list.

4.6.5 Saving a Model

To save a model, select the **File|Save** menu item. If the file has not been saved before, the ***Save As*** dialog box will be brought up and you will be requested to assign the model a filename. For our example, type dipole, EAM will automatically add the file extension .nec. If the model has previously been assigned a name, it will again be saved to that name.

To save a model under a new name, select the **File|Save As** menu item.

All saved models are written to an ASCII file in the standard NEC format.

4.6.6 Running an Analysis

To begin an analysis of the active Antenna Definition Window, select the **Run** menu item. EAM-NEC will automatically save the input file and launch NEC. The input and output file names are passed to NEC and the user is notified that the analysis is under way. While the analysis is running, the cursor will be displayed as a working clock. An important feature of EAM-NEC is that you can take advantage of Windows™' multi-tasking ability and switch to another application while the analysis is running. You will be notified with a beep when the analysis is completed.

Previously generated files written in the standard NEC input format can be read and executed by EAM-NEC. EAM-NEC version 1.0, however, has some limitations on the model geometry and control lines it will recognize. Please read the EAM-NEC Capabilities section for more information.

4.6.7 Viewing NEC Output Data

Plotting output data with EAM-NEC is as easy as selecting a menu item and specifying a filename to plot. Once a filename is specified, the data is read into memory and plotted. Because EAM-NEC gives you the capability to open multiple plots windows simultaneously, comparisons of output data become quick and easy.

EAM-NEC offers two types of output plots: polar radiation pattern plots and current distribution diagrams. In addition to being completely independent of the input file, plotting with EAM-NEC does not require any special processing of the NEC output file. It does not perform any reformatting or editing of NEC output files. Instead, it reads the NEC generated files for desired information and plots the data in the form of color plots. NEC data obtained from pre-EAM-NEC output files, including those generated on a main-frame computer can also be graphically displayed. In other words, huge models can be easily created with the EAM-NEC, transferred to a main frame computer for execution, and then the output file can be transferred back to the PC for graphical display, as shown in Figure 4.6-7.

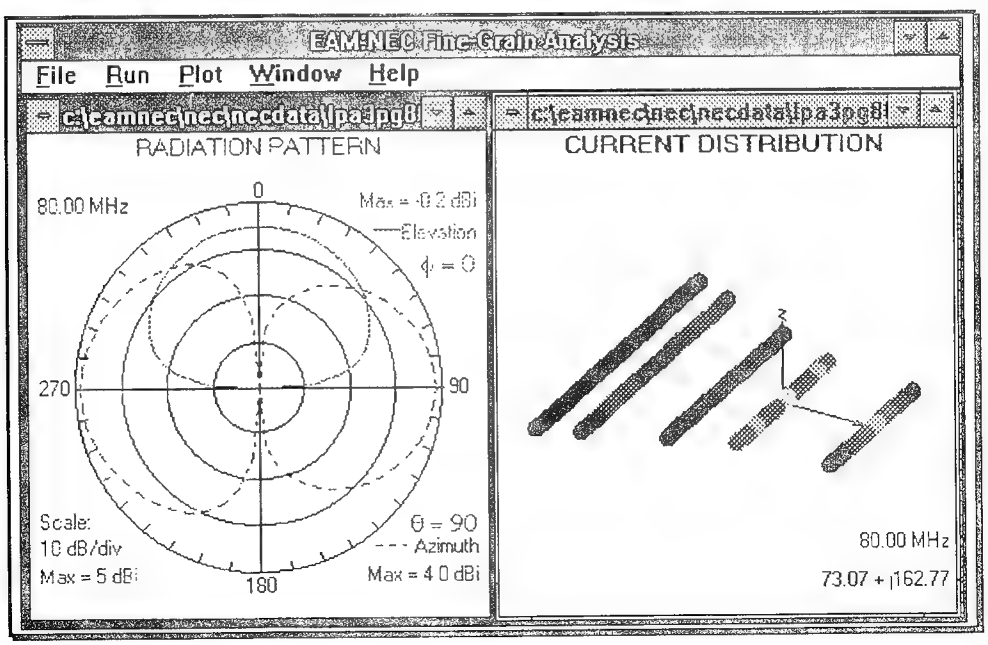


Figure 4.6-7. Radiation Pattern and Current Distribution Plots

Opening the Dipole Radiation Pattern:

To bring up the dipole output data plot after running an analysis, select either the **Plot|Open|Radiation Pattern** menu item. These commands will bring up a *File Open* dialog box containing existing filenames and directories. Selecting a dipole.out and "OK" will cause EAM-NEC to read in the data and display the appropriate plot. The result will resemble Figure 4.6-8, with both the drawing window and the radiation pattern displayed simultaneously.

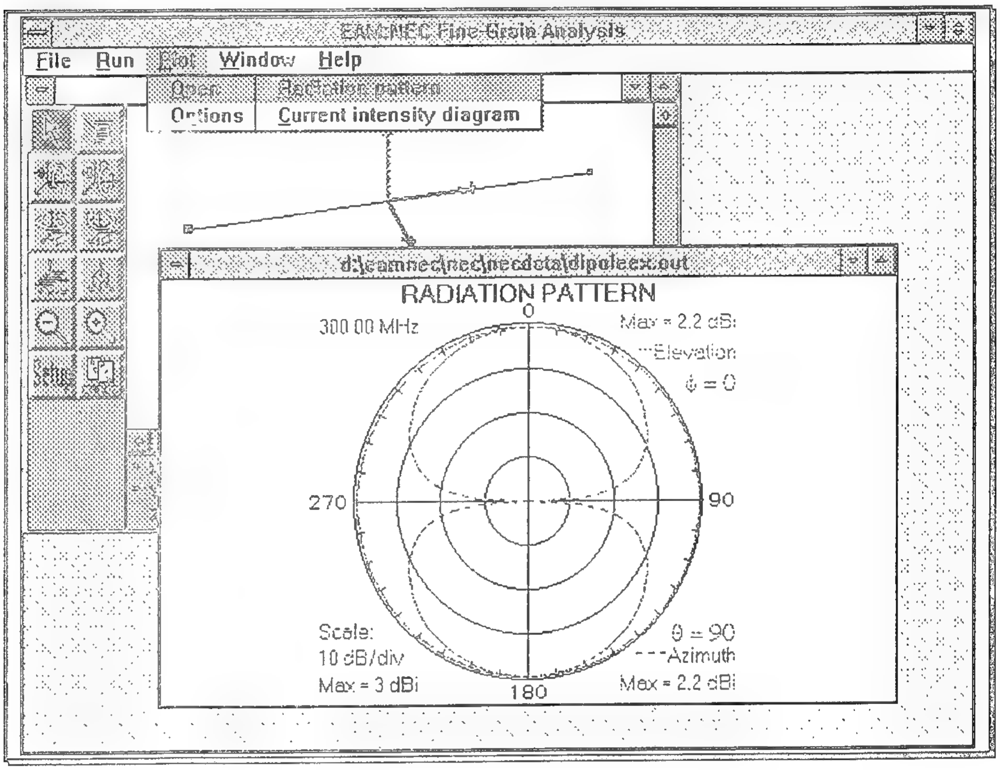


Figure 4.6-8 Drawing Window With Radiation Pattern

Changing the Radiation Pattern Parameters:

Associated with each plot are parameters which can be modified with the options dialog box. The radiation pattern options dialog box can be accessed via the menu bar using **Plot|Options** when a plot window is active. Figure 4.6-9 shows the options dialog box used for radiation patterns.

Parameters listed include:

Pattern # in file

If an output file has multiple data sets, you can use this field to specify which data set to plot.

Elevation plot

This group of options corresponds to elevation data. A check mark in the ***Plot data*** box indicates that elevation data will be displayed. Below the ***Plot data*** box you have the option to select ***Show both hemispheres***, data from -180 to +180 degrees, or ***Show upper hemisphere only***, data from -90 to +90 degrees. The final parameter for the elevation data is *Phi (deg)*, the angle which specifies the elevation cut to be displayed.

Azimuth plot

This group of options corresponds to Azimuth data. A check mark in the ***Plot data*** box indicates that azimuth data will be displayed. The only other parameter for the azimuth data is *Theta (deg)*, the angle which specifies the azimuth cut to be displayed.

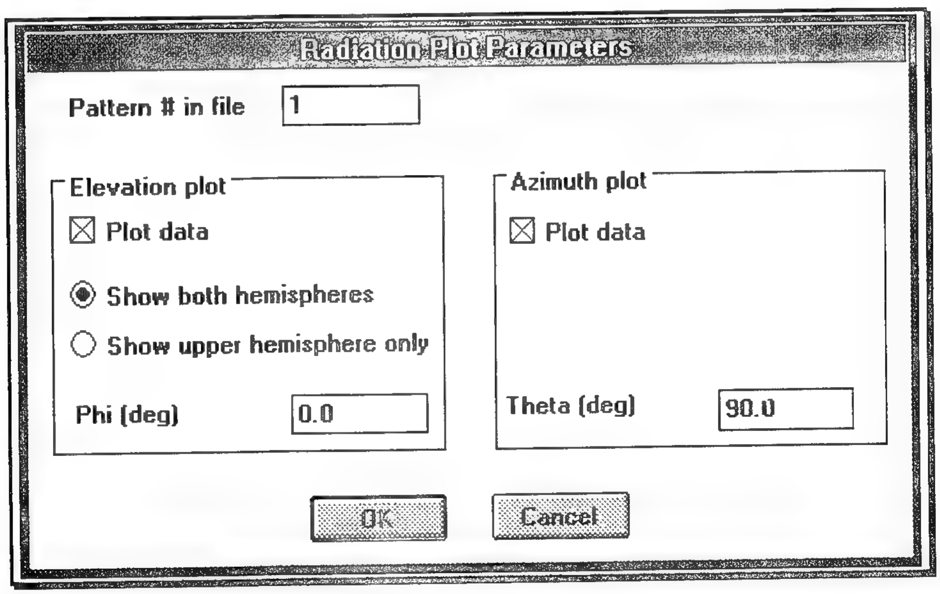


Figure 4.6-9. Options Dialog Box for Radiation Patterns

Opening the Dipole Current Distribution Diagram:

To bring up the current distribution output data plot after running an analysis, select either the **Plot|Open|Current Intensity Diagram** menu item. These commands will bring up a ***File Open*** dialog box containing existing filenames and directories. Selecting a dipole.out and "OK" will cause EAM-NEC to read in the data and display the appropriate plot. The result will resemble Figure 4.6.10, with both the Current distribution diagram and the options are displayed simultaneously.

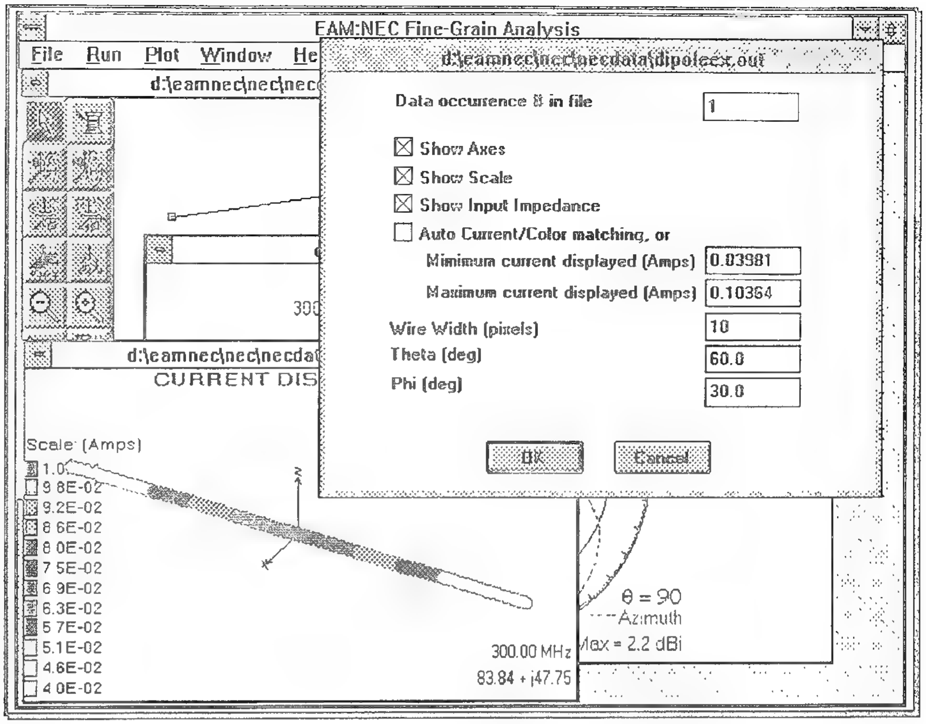


Figure 4.6-10. Current Distribution Diagrams and Options Dialog Box

Changing the Current Distribution Parameters:

Associated with each plot are parameters which can be modified with the options dialog box. The current distribution options dialog box can be accessed via the menu bar using **Plot|Options** when a plot window is active. Figure 4.6-10 shows the options dialog box used for radiation patterns.

Parameters listed include:

Data occurrence # in file

If an output file has multiple data sets, you can use this field to specify which data set to plot.

Show Axes, Show Scale, Show Input Impedance

A check mark in each of these boxes indicates that the coordinate system axes, the current intensity legend, and antenna's calculated input impedance will be displayed, respectively.

Auto Current/Color Matching

A check mark in this box indicates that each current value will automatically be assigned a specific color according to its magnitude.

Wire Width (pixels)

This value represents the thickness of the wires (lines) making up the antenna model. This is only for display purposes and has no effect on the physical characteristics of the antenna.

Theta (deg), Phi (deg)

These values represent the orientation of the antenna model in the coordinate system.

The plot options mentioned above also apply to open plots. If you wish to plot different data from within the same data file, you can specify this via the **Plot|Options** menu item. Selecting this will bring up the options dialog box for the active plot. You can then re-specify the plot parameters.

4.6.8 Printing

Select the **File|Print** menu item to print. The EAM-NEC print routine is a screen dump so the result will be identical to what is displayed on the monitor.

After selecting **File|Print**, a Print dialog box will be displayed with the following options: *Use Printer Resolution*, *Scaling* and *Number of Copies*.

The *Use Printer Resolution* option will print at printer resolution rather than screen resolution.

The *Scaling* option will increase or decrease the relative size of the printout.

The *Number of Copies* option specifies how many copies are desired.

4.7 EAM-NEC CAPABILITIES

Presently, EAM-NEC is set up for the modeling of wire frame geometry. It does not include any of the patch features. This was done because the patch algorithm in NEC uses the magnetic field integral equation which requires the patch models to be closed surfaces. Since NEC development, an algorithm has been developed to analyze patch models with the electric field integral equation, which does not require a closed surface.

EAM-NEC was designed for both inexperienced and experienced users. One of the control lines, labeled "miscellaneous", can be used to construct any control line which NEC has to offer. This makes all NEC feature available to the experienced user.

Presently, EAM has a intuitive drawing package which allow drawing of wires, stretching of wires, and the direct editing of wires, but it does not allow for duplication of a wire. This can be overcome by using the **open as text feature**. In the text editor a GW line or group of GW lines can be copied and quickly modified, saved and then reopened as a drawing window.

Notes on EAM-NEC

Caution should be used when modifying wire endpoint with the wire parameters dialog box. Upon closing the dialog box the wire ends values will reset to the largest size which fits within the setup size.

5 BASIC SCATTERING CODE MODULE (EAM-BSC)

The Basic Scattering Code module provides the capability for complete antenna analysis with solid geometry using a graphical user interface (GUI) which encompasses the Basic Scattering Code (NEC-BSC). The GUI includes a 3D model definition window to help the user visualize the model, error checking, and user-friendly dialog boxes to accurately specify BSC control parameters. Also included is the capability to rapidly display linear electric field strength plots and radiation intensity plots in the far field for Theta, Phi and Frequency.

Chapter 5 is divided into seven subsections. The first subsection, 5.1, is an overview of EAM-BSC from antenna definition through BSC execution to displaying the results. Subsection 5.2 discusses the menu bar which provides the major interface to storage devices, printing, execution of BSC, selecting output desired, screen management and access to the help system. Subsection 5.3 provides a detailed discussion of the model definition window. Subsection 5.4 discusses the tool bar and all the features provided by each tool buttons. Subsection 5.5 describes the functions and commands that can be activated using the keyboard and mouse. Subsection 5.6 provides a tutorial for the inexperienced user. The last subsection, 5.7, provides a discussion on features which were not implemented in EAM-BSC due to a combination of fiscal and schedule constraints.

5.1 EAM-BSC OVERVIEW

The Electromagnetic Antenna Modeling System-BSC (EAM-BSC) consists of a customized model definition/drawing processor and a data post-processor. It is intended to be used for antenna analysis targeted at both experienced and novice electromagnetics (EM) engineers. Because of the anticipated broad range of user experience, the application was designed to support all of NEC-BSC's sophisticated antenna analysis features while also being intuitive enough to mitigate the most common deficiency of NEC-BSC, i.e., user error.

EAM-BSC is designed to run on a 80386/486 PC with Windows™ 3.0 or higher running in enhanced mode. It is a customized, intuitive, graphical user interface (GUI) for NEC-BSC. EAM-BSC has three main functions: 1) to graphically define the antenna and its environment; 2) to save the

model and execute the analysis; 3) to read, process, and display user-specified data. The major components that make up the EAM-BSC include: a main menu, a model pre-processor, a transparent execution interface, a data post-processor, and an on-line help system

5.1.1 Model Definition

A key feature of EAM-BSC is the model definition window. By design, it has the look and feel of a typical Windows™ vector-based drawing package. EAM-BSC, however, employs additional features for drawing in 3D and automating the tedious work of typing plate, cylinder, cone, etc., coordinates in a DOS text file. As shown in Figure 5.1-1, the window contains a model title, drawing area, tool bar for structure and view manipulation, scroll bars, and specific model information.

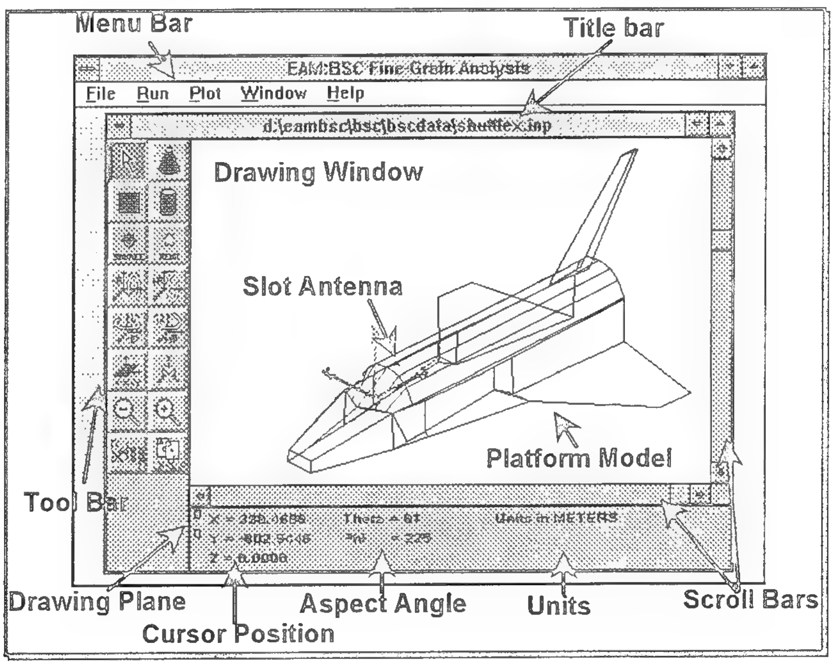


Figure 5.1-1. EAM-BSC Model Definition Window

5.1.2 NEC-BSC Execution

NEC-BSC, the computational engine in EAM-BSC, is recognized as a gold-standard in Geometry Theory of Diffraction (GTD) codes and is used for predicting the performance of antennas and their platform when the size is grater than a few wavelengths. Its core computation is ray tracing using reflection, diffraction, refractions, and various surface mode propagation to compute and superimpose the complete scattered electromagnetic field. Computational time is directly related to the number of field points required and the number of scatterers. NEC-BSC,

like most text-based engineering tools, is user unfriendly and requires extensive knowledge and experience to be used correctly and effectively.

Running a NEC-BSC analysis is accomplished by selecting the *Run* menu item. EAM-BSC automatically creates and saves an input file for the active model definition window, and then transparently executes NEC-BSC. Once an analysis has begun, the cursor changes to a rotating wheel, signifying execution is in process. At this time, you can take advantage of Windows™' multi-tasking capability and switch to another application. EAM-BSC will notify you when the analysis is through. Figure 5.1-2 demonstrates the selection of the *Run* menu item and the prompt dialog box.

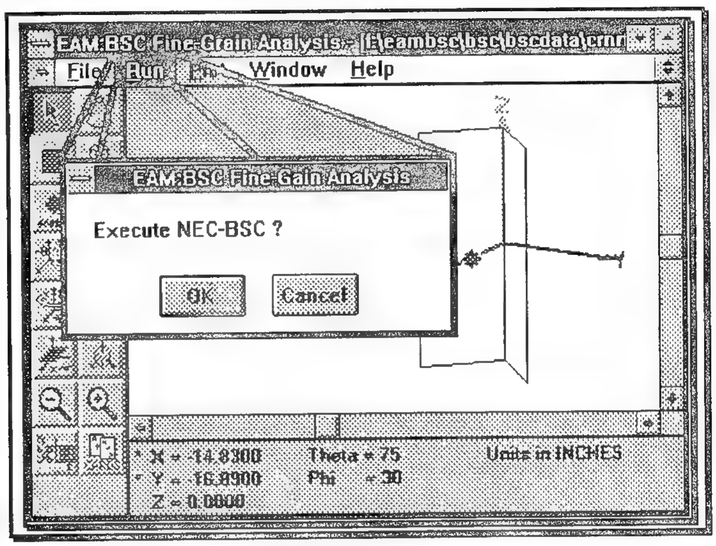


Figure 5.1-2 BSC Execution Dialog Box

5.1.3 Output Processing and Displays

Presently, EAM-BSC is capable of displaying far-field and radiation data for both angle and frequency sweeps. (An upgrade that incorporates near-field plots is near completion). It does not perform any reformatting or editing of NEC-BSC output files. Instead, it reads the NEC-BSC generated files for desired information and plots the data in the form of color linear plots, as shown in Figure 5.1-3. Here, both E-plane and H-plane E-Field patterns are displayed simultaneously on a single plot. The two patterns are distinguished by both line color and texture.

Data obtained from existing output files, including those generated on a main-frame computer can also be graphically displayed. In other words, huge models can be easily created with the EAM-BSC, transferred to a

main frame computer for execution, and then transferred back to the PC for graphical display.

One of the most useful features of EAM-BSC is the ability to display multiple windows on the screen simultaneously. Figure 5.1-3, for example, displays a model and two of its output plots, E-field and radiation intensity.

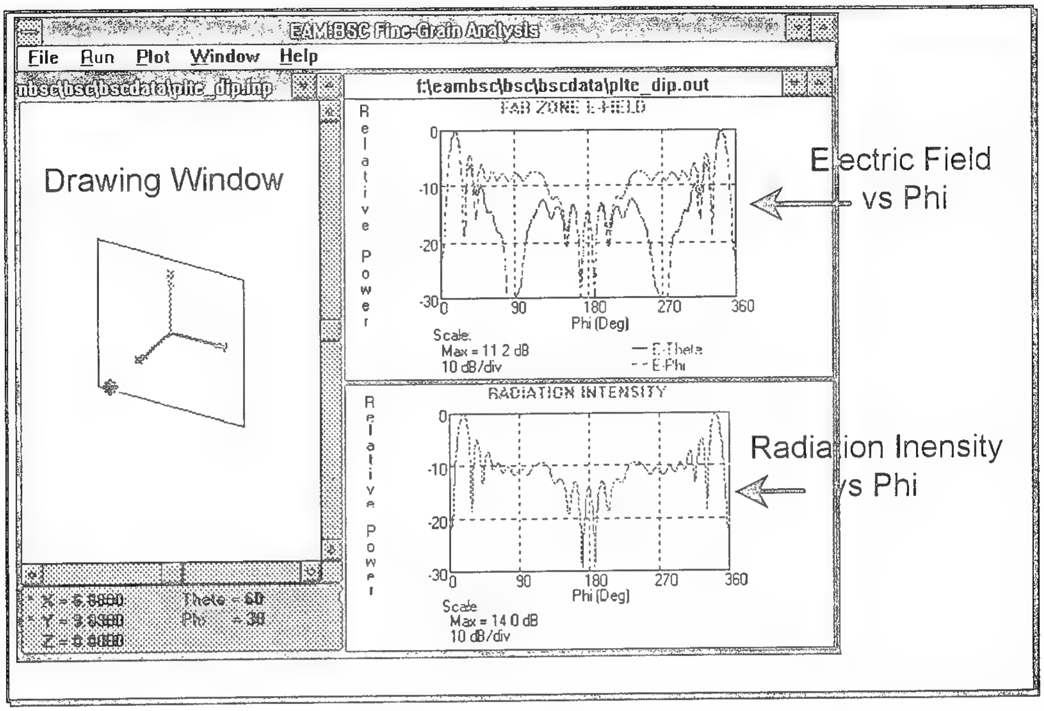


Figure 5.1-3 Two BSC Output Displays Tiled with the Model Definition Window

5.2 EAM-BSC MENU BAR

The EAM-BSC Menu Bar is located near the top of the application window, just below the Title Bar, as shown in Figure 5.2-1. The menu's top-level selections, which include **File**, **Run**, **Plot**, **Window**, and **Help,** allow you to access files, run an analysis, plot output data, select plot options, configure the windows on the screen, and activate the help system. The following sections describe each of the menu items.

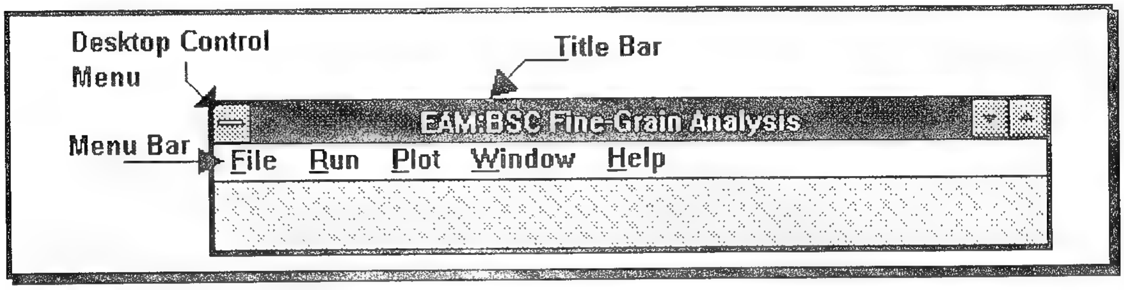


Figure 5.2-1. The EAM-BSC Main Menu

5.2.1 File Menu

The **File** menu allows you to open, save, and print new and existing models. These features are accessed via sub-menu items: **New**, **Open**, **Open As Text**, **Save**, **Save As**, **Print**, **Print Setup**, and **Exit**.

New

The **File|New** menu item is used to open a new Model Definition Window. The window is created with a blank drawing area containing the XYZ axes and preset default drawing options.

Open

The **File|Open** menu item is used to open an existing NEC-BSC input file. Upon selection of **File|Open**, EAM-BSC provides a dialog box for specification of a path and filename. The default file extension that EAM-BSC searches for is '.inp', however, the user may alter this. After selecting a valid file, the corresponding model will be displayed graphically and all control lines will be listed in the Control Line Editor.

Open As Text

The **File|Open As Text** menu item is used to open an existing ASCII text file. Upon selection of **File|Open As Text**, EAM-BSC provides a dialog box for specification of a path and filename. The specified file will be opened and displayed as text in a text editor window. This a generic text editor that can make and save changes to a file.

Note: presently, the maximum file size that the text editor can read in is approximately 30 KB. Larger files can be opened and viewed, however, they will be truncated. If a file larger than 30 KB is opened and saved, the truncated information will be lost.

Save

The **File|Save** menu item allows the user to save the model in the active Model Definition Window (Drawing Window) to a file. **File|Save** uses a previously defined file name if one exists, otherwise it prompts you for a new file name. All models are saved in NEC-BSC input format. It is recommended that all EAM-BSC models use '.inp' for the filename's extension.

If the active window is the text editor window, File|Save will save in ASCII format.

Because NEC-BSC output data is automatically saved to a file, plots of the output data can not be saved. The output file data remains unchanged regardless of how many times you plot it.

Save As

The **File|Save As** menu item allows the user to save the model in the active Model Definition Window (Drawing Window) to a new filename. All models are saved in NEC-BSC input format. Use this command to save an existing file with a new name. It is recommended that all EAM-BSC models use '.inp' for the filename's extension.

If the active window is the text editor window, File|Save As will create a new file and save in ASCII format.

Because NEC-BSC output data is automatically saved to a file, plots of the output data can not be saved. The output file data remains unchanged regardless of how many times you plot it.

Print

The **File|Print** menu item allows you to create hard copy outputs of the screen using the default printer. These outputs are provided as a screen dump of the entire monitor display. **File|Print** also allows you to specify the number of copies and scaling of the image. The **File|Print Setup** menu item allows you to change the parameter settings of the default printer. Use the Program Manager's Control Panel to activate a different printer as the default printer.

Note: If the EAM-BSC window is maximized, a scaling selection of 140% will completely fill an 8 1/2x11 sheet of paper.

Exit

The **File|Exit** menu item allows you to close the EAM-BSC application. You will be prompted to save any newly created or modified models upon selection of this menu item.

5.2.2 Run Menu

The Run menu allows you to initiate analysis of the active model using NEC-BSC. EAM-BSC will spawn NEC-BSC and pass it the input and output file names. The output file name is always the same as the input file name (the active Model Definition Window with a '.out' file extension. If the output file name already exists, you will be warned and prompted whether or not to discard the old data and to replace it with the new data. If you select not to replace the old data, a new output file will automatically be created using a different name.

While the analysis is running EAM-BSC will be in an idle state and will display a running cursor. You are free to switch to another application while the analysis is active. EAM-BSC will notify you when the analysis is through.

Note: The model is automatically saved immediately prior to each execution of an analysis. This means that if you have made changes to an input model and run the analysis, the original saved model will be overwritten. If the model has never been saved, you will be notified and the File|Save As dialog box will be brought up.

5.2.3 Plot Menu

The **Plot** menu allows you to graphically display far field patterns contained in NEC-BSC output files. The files need only to be in the typical NEC-BSC output format and do not have to be created using EAM-BSC, i.e., output files from other platforms running NEC-BSC may also be plotted.

With the **Plot** menu items, you have the capability to open multiple plot windows simultaneously. This allows for quick and easy comparisons of data from the same output file or from different files. In addition, certain plot options can be set from within this menu. All These features are accessed via the following sub-menu items: **Far Field** and **Options**.

Far Field

The **Plot|Far Field** menu item allows you to specify the drive, directory, and filename of an existing NEC-BSC output file to be plotted. The default file extension that EAM-BSC searches for is '.out', however, you may alter this. After selecting a file, EAM-BSC automatically searches the file for far field output data. If data is found, the Plot Options dialog box is brought up to allow you to specify the data to be plotted, otherwise, you are notified that no far field data was found.

Options

The **Plot|Options** menu item brings up a dialog box which allows you to specify parameters of the active plot window. Parameters include:

Far Field Pattern Type

Electric Field
Radiation Intensity

Plot Data Set

This is a drop down list box that contains the number of plottable data sets found in the specified file. You can select any one of the data sets for the plot.

This menu item is available only when a plot window is active. The same Plot Options dialog box is also brought up when a new plot is opened.

5.2.4 Window Menu

The **Window** menu allows you to manipulate the display of open windows. Sub-menu items include: **Cascade**, **Tile**, **Arrange Icons**, and **Close All**.

Cascade

The **Window|Cascade** menu item re-sizes and layers all open windows. It automatically arranges the windows so that they are neatly stacked on the screen in an overlapping fashion, from left to right, top to bottom, with only the window title showing.

Tile

The **Window|Tile** menu item re-sizes and re-positions all open windows so that they are all visible on the screen concurrently. The windows are arranged so that they are as big as they can be without overlapping each other. This is a quick way to neatly display all windows.

Arrange Icons

Selection of **Window|Arrange Icons** causes all window icons to be neatly displayed along the bottom of the EAM-BSC application window. Icons are used to represent windows that are open but have been minimized by the user to reduce screen clutter.

Close All

The **Window|Close All** menu item automatically closes all EAM-BSC windows. You will be prompted to save files when necessary. Only windows are closed, the application remains active.

5.2.5 Help Menu

EAM-BSC includes a comprehensive, on-line help system. This help system can be accessed via the **Help** menu. The **Help** menu includes two sub-menus: **Index**, and **About EAM-BSC**.

Index

Selecting the **Help|Index** menu item causes EAM-BSC to activate the help system. The help system will display an index of available information for all the EAM-BSC menus and features. Topics highlighted in green indicate that additional information is available. This information can be accessed by simply pointing and clicking on the desired topic.

This command can also be activated with the "F1" function key.

About EAM-BSC

The **Help|About EAM-BSC** menu item brings up a dialog box to display the application version number, a copyright notice, and the serial number.

5.3 THE MODEL DEFINITION WINDOW

The Model Definition Window (MDW) is the focal point for drawing and defining the NEC-BSC input model. From within this window, you can use the mouse to draw the physical structure of the model, specify sources and receivers, and define the program control lines. The window is divided up into three separate areas: the drawing area, the tool bar, and the information window (info window). Each of these is pointed out in Figure 5.3-1.

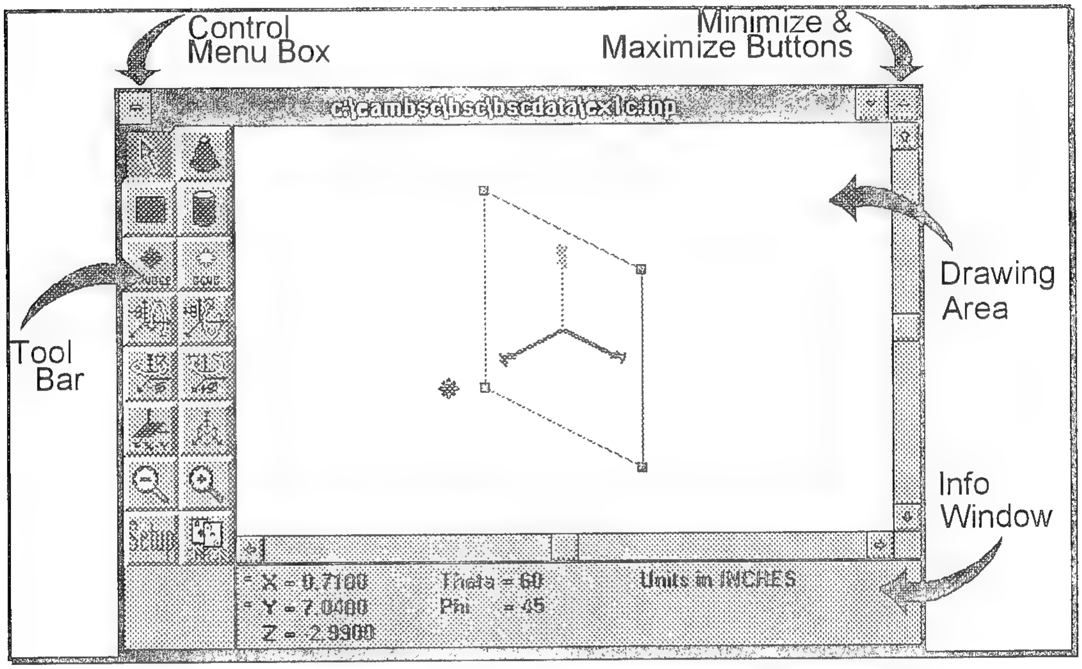


Figure 5.3-1. The Model Definition Window.

The MDW can be used to define a complete input file. It is titled to indicate the file name and path, or in the case of an unsaved model, the MDW is labeled as ***untitled***. The MDW can be moved and re-sized within the EAM-BSC application window, creating a larger, or smaller, drawing area. The size and relative position of the tool bar and the info windows always stays the same. If the MDW is resized so that it is narrower or shorter than these, they will be truncated.

The Drawing Area will display all the physical features of the input model. Although the model is created with solid structures, EAM-BSC can only display its outline, i.e. all solids appear transparent. The window always comes up with the three axes centered. The model magnification and orientation can be varied from the Tool Bar, and the vertical and horizontal scroll bars can be used to move the drawing area left/right and up/down. The resolution of the mouse movements while drawing within the Drawing Area, i.e. the snap-to-grid resolution, can be adjusted using

the Set Up tool from the Tool Bar. Using Set Up, you can also change the maximum allowable dimension for the input model.

Directly to the left of the Drawing Area is the Tool Bar. The Tool Bar contains all the available tools for drawing and defining a model and its parameters, as well as for manipulating the model view. The function each tool provides applies only in the MDW. The Tool Bar is discussed in greater detail in Subsection 5.

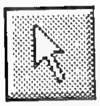
Located below the Drawing Area is the Info Window. As its name suggests, the Info Window contains information specific to the model. This includes, the XYZ location of the cursor, the Theta and Phi values for the viewing orientation, the measurement units used to define the structure, and the drawing plane the cursor is moving in. As you can see in Figure 5-3, the cursor location is indicated in the left side of the Info Window. Along side two of the labels, in this case X and Y, there are asterisks. These two asterisks represent the drawing plane (the plane the mouse is in), which in this case, is the XY plane. These asterisks are automatically updated whenever the drawing plane is changed. If the viewing orientation of the model is changed so that the drawing plane is no longer visible (the plane looks like a line), the cursor will act as if it is frozen. This can be quickly remedied by changing the drawing plane.

5.4 THE TOOL BAR

The tool bar is located on the left side of the Model Definition Window (MDW). It contains all the available tools for drawing and defining a model and its parameters, as well as for manipulating the model view. The function each tool provides applies only in the MDW.

The following sections will describe each tool individually.

5.4.1 The Arrow Tool



This is the default tool for model construction in EAM-BSC. Selecting "Arrow Tool" button will change the cursor to an arrow and will activate the arrow tool functions. There are several functions associated with the arrow tool when operating in the Model Definition Window. These include:

Selecting a Building Block

Models are built using solid geometric building blocks, i.e., plates and cylinders. With the arrow tool, you can select and activate any model building block. This can be accomplished simply by clicking the mouse once within the area of a building block. Once a building block is selected, it will be highlighted in red and will have small black square markers around its perimeter. The exception to this will be the cylinder which will only be highlighted in red.

Stretching Plate Sides

When a plate is selected, the arrow tool can be used to change the location of its corners individually, thereby stretching or shrinking a two of its sides. To modify a plate, simply select the corner that is to be moved and, while holding the left mouse button down, drag it to a new location. The plate's parameters are automatically updated to include the new location coordinates.

Changing a Source or Receiver Location

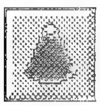
When a source or receiver is selected, the arrow tool can be used to move it to a new location. A location change is accomplished by clicking on the source (or receiver) and, while holding the left mouse button down, dragging it to new coordinates. Upon dragging, the cursor will temporarily change from an arrow to a source (or receiver) until the mouse button is

released. The source (or receiver) parameters are automatically updated to include the new location's coordinates.

Activating the Building Block Parameter Dialog Box

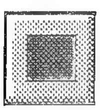
Using the arrow tool, it is possible to activate and display a dialog box that allows you to view and edit a building block's parameters, i.e. the parameters of a plate or cylinder, etc.. This can be accomplished in a fashion similar to selecting a building block, however, this time the mouse must be double-clicked. Double-clicking within the building block's area will automatically select the block and bring up its parameters dialog box.

5.4.2 The Cone Frustum Tool



The Cone Frustum Tool has not been implemented at the time of release of version 1.0.

5.4.3 The Plate Tool



Selecting the "Plate Tool" button activates the plate drawing tool and changes the MDW cursor to a plate cursor. This cursor signifies that you are in the plate drawing mode. All parameters for a new plate, geometric as well as non-geometric, are defined in this mode.

Plate Default Parameters

Each new plate is given default values for non-geometric parameters, i.e. plate type, dielectric layers, etc. These default values can be displayed and modified by double-clicking on the "Plate Tool" button. This action brings up a Plate Defaults dialog box which can be edited. After the parameters in the Plate Defaults dialog box are edited, each new plate drawn will be assigned the new values.

Plate Coordinates

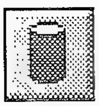
In NEC-BSC, a plate is defined by the number of corners and their location relative to the coordinate system origin. In the plate drawing mode, the mouse is used to define the coordinates of new plate corners. The first corner is specified by simply clicking the mouse at the desired coordinates. Each subsequent corner is similarly specified by moving the mouse in the model definition window and clicking at the location of each

new corner. To complete a plate, the last mouse click location must be precisely on the first corner location.

It is important to note that all plate coordinates are automatically entered into the NEC-BSC input file in the order in which they are defined.

Hint: double-clicking at the last corner location automatically closes the plate.

5.4.4 The Cylinder Tool



Selecting the "Cylinder Tool" button activates the cylinder drawing tool and changes the MDW cursor to a cylinder cursor. This cursor signifies that you are in the cylinder drawing mode. All parameters for a new cylinder are defined in this mode.

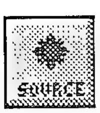
Cylinder Default Parameters

Each new cylinder is given default values for specific geometric parameters, i.e. orientation, radius, etc. These default values can be displayed and modified by double-clicking on the "Cylinder Tool" button. This action brings up a Cylinder Defaults dialog box to be viewed and edited. After the Cylinder Defaults dialog box parameters are edited, each new cylinder drawn will be assigned the new values.

Cylinder Coordinates

The only cylinder parameter defined with the mouse in the cylinder drawing mode is the cylinder coordinate system origin. It is specified simply by clicking in the model definition window at the desired location. A new cylinder that exhibits the default values will be placed at that location.

5.4.5 The Source Tool



Selecting the "Source Tool" button activates the source drawing tool and changes the MDW cursor to a source cursor. This cursor signifies that you are in the source drawing mode. All parameters for a new source are defined in this mode.

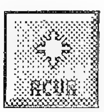
Source Default Parameters

Each new source is given default values for specific geometric and non-geometric parameters, i.e. orientation, excitation, etc. These default values can be displayed and modified by double-clicking on the "Source Tool" button. This action brings up a Source Defaults dialog box which can be viewed and edited. After the Source Defaults dialog box parameters are edited, each new source drawn will be assigned the new values.

Source Coordinates

The only source parameter defined with the mouse in the source drawing mode is its location relative the coordinate system origin. It is specified simply by clicking in the model definition window at the desired location. A new source that exhibits the default values will be placed at that location.

5.4.6 The Receiver Tool



Selecting the "Receiver Tool" button activates the receiver drawing tool and changes the MDW cursor to a receiver cursor. This cursor signifies that you are in the receiver drawing mode. All parameters for a new receiver are defined in this mode.

Receiver Default Parameters

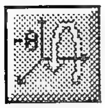
Each new receiver is given default values for specific geometric and non-geometric parameters, i.e. orientation, excitation, etc. These default values can be displayed and modified by double-clicking on the "Receiver Tool" button. This action brings up a Receiver Defaults dialog box which can be viewed and edited. After the Receiver Defaults dialog box parameters are edited, each new receiver drawn will be assigned the new values.

Receiver Coordinates

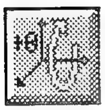
The only receiver parameter defined with the mouse in the receiver drawing mode is its location relative to the coordinate system origin. It is specified simply by clicking in the model definition window at the desired location. A new receiver that exhibits the default values will be placed at that location.

5.4.7 The Rotate Theta (θ) Tool

Theta is measured as the angle between the positive Z-axis and a line drawn perpendicular to the screen from the origin.



Selecting this button will rotate the entire model so that theta is decremented. The curved arrow shows the apparent rotation of the model.

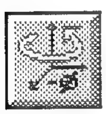


Selecting this button will rotate the entire model so that theta is incremented. The curved arrow shows the apparent rotation of the model.

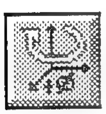
The delta for rotation in theta can be customized by selecting the "Set Up Tool" button (the default is 15 degrees).

5.4.8 The Rotate Phi (ϕ) Tool

Phi is measured as the angle between the positive X-axis and the projection in the Z=0 plane of a line drawn perpendicular to the screen from the origin. Phi is always measured in the positive Y direction.



Selecting this button will rotate the entire model so that phi is decremented. The curved arrow shows the apparent rotation of the model.



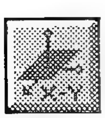
This button will rotate the entire model so that phi is incremented. The curved arrow shows the apparent rotation of the model.

The delta for rotation in phi can be customized by selecting the "Set Up Tool" button (the default is 15 degrees).

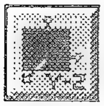
5.4.9 The Rotate Plane of View Tool

Standard Plane Configurations

There are three functions and faces associated with this one button, as shown below.

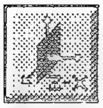


X-Y Rotate the model so that the user's view is normal to the XY-plane (θ=0, ϕ=0).



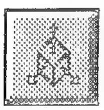
Y-Z Rotate the model so that the user's view is normal to the YZ-plane. (θ=90, ϕ=0)

Z-X Rotate the model so that the user's view is normal to the ZX-plane (θ=90, ϕ=90).



These functions are all part of a rotation that advances each time the button is selected. With each button click, the next function, and tool button face representative of the function, is called. For example, the first time the button is pressed, the model will be rotated to the XY-plane. If the button is pressed again, the model will be rotated to the YZ-plane. One more press will rotate the model to the ZX-plane, and another back to the XY-plane. This rotation sequence always begins in the XY-plane.

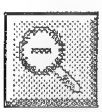
Isometric View



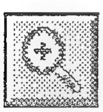
This button will rotate the model so that it is viewed from an isometric perspective (θ=45, ϕ=45).

5.4.10 The Zoom-Out and Zoom-In Tools

These tools vary the magnification of the drawing area in the MDW.

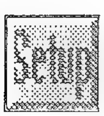


Reduces the magnification of the drawing area.



Increases the magnification of the drawing area.

5.4.11 The Set Up Tool



This button allows you to customize several settings for drawing in the MDW. The available options are listed below.

Max Model Dimension

This value controls the maximum model coordinate that can be specified. For new models, it is suggested that you specify a number approximately 20% larger than the maximum desired coordinate location. For existing models, this option is automatically set at 25% beyond the largest coordinate location. This setting is primarily to allow for a reasonably sized drawing area to be created.

Grid Resolution (Grid spacing)

This value controls the snap-to-grid resolution. For new models, it is easiest to draw when the maximum grid resolution is used, i.e. use a course resolution for the basic framework and then a finer grid resolution for detailed work. For example, if a model is to be created in 0.5 meter increments, the grid resolution should be set to 0.5. A setting of anything less would be unnecessary, and could even create a more difficult environment to work in. Existing models are automatically scanned for the maximum allowable grid resolution.

Angles

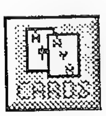
Theta Set Theta to a specific angle.

Phi Set Phi to a specific angle.

Theta Increment Set the increment associated with the "Rotate Theta" tool buttons.

Phi Increment Set the increment associated with the "Rotate Phi" tool buttons.

5.4.12 The Control Line Editor Tool



Selecting the "Cards Tool" button activates the control line editor. The editor is custom designed to help simplify the specification of a model's control lines, i.e. excitation, frequency, output, etc. It provides the capability to add new lines, delete old lines, modify the contents and order of existing lines, and even to create a default list to be used with other models. Figure 5.4-1 shows the control line editor with all its options.

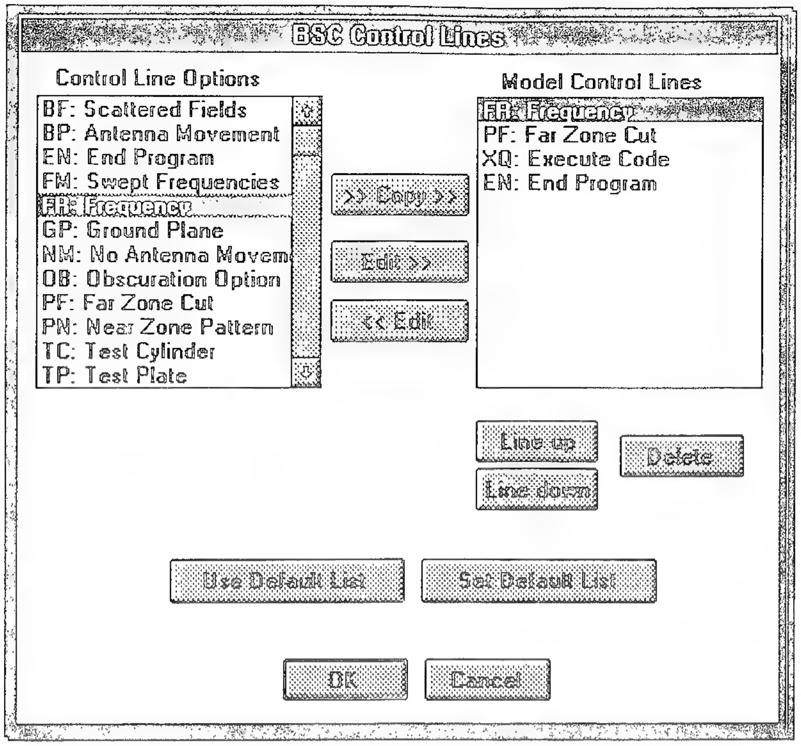


Figure 5.4-1. The Control Line Editor

Editor Parameters

Control Line Options This is a list of the control lines available for use with the model (shown on left of editor). Use the scroll bar to view all available lines.

Model Control Lines This is a list of the control lines selected for this model (shown on right of editor). Figure 5-1 shows four control lines used to define the frequency, to compute a far zone cut, to execute the model, and to end the program.

Editor Options

>> Copy >> Select ">>Copy>>" to duplicate a control line from the Control Line Options list to the Model Control Lines list. The copied card will retain all the settings of the original card.

Edit >> Select "Edit>>" to view and edit a control line's parameters from the Model Control Lines list.

<< Edit Select "<<Edit" to view and edit the default values for a control line from the Control Line Options list. The new values will be stored and will be available to other models.

New values are retained only when the Control Line Editor OK button is selected.

Line Up Select "Line Up" to move the position of a highlighted control line forward in the Model Control Line list.

Line Down Select "Line Down" to move the position of a highlighted control line backward in the Model Control Line list.

Delete Select "Delete" to remove a control line from the Model Control Line list.

Use Default List Select "Use Default List" to clear the existing Model Control Line list and replaces it with a user defined default list.

Set Default List Select "Set Default List" to store the existing Model Control Line list as the Default List. The default list can then be recalled with the "Use Default List" button.

OK Select "OK" to close the Control Line Editor and save all the changes made while it was open.

Cancel Select "Cancel" to close the Control Line Editor and discard all the changes made while it was open. This includes changes made to the default list.

Note: For information regarding control line specifications and model requirements, please consult with the NEC-BSC User's Manual.

5.5 KEYBOARD AND MOUSE COMMANDS

This section will describe various functions and commands that can be activated using the keyboard and mouse.

5.5.1 Moving the Cursor with the Keyboard

In addition to the mouse, the keyboard can be used to move the drawing cursor within the Model Definition Window. The keyboard commands can be used for movement in all directions, or, when used together with the mouse, it can be used to restrict movement to a single direction. Below is a list of keystrokes and their function.

Key(s)	Function
X (Ctrl X)	Moves the cursor in the positive (negative) X direction. Each keystroke increments (decrements) the cursor position by 1 grid spacing. Grid spacing can be customized with the Set Up Tool.
Y (Ctrl Y)	Moves the cursor in the positive (negative) Y direction. Each keystroke increments (decrements) the cursor position by 1 grid spacing. Grid spacing can be customized with the Set Up Tool.
Z (Ctrl Z)	Moves the cursor in the positive (negative) Z direction. Each keystroke increments (decrements) the cursor position by 1 grid spacing. Grid spacing can be customized with the Set Up Tool.
H or Home	Both of these keys will move the cursor to the coordinate axes origin.
Shift	Shift restricts the movement of the cursor to a single plane. For example, if the XY-plane is selected and shift is pressed, moving the mouse in the drawing area will vary the cursor location only in the ±X direction. Shift + YZ-plane allows cursor location to vary only in ±Y, and Shift + ZX-plane only in ±Z. **Shift** applies to cursor movement via keystrokes as well as the mouse.

5.5.2 Deleting Model Building Blocks with the Keyboard

Two steps are required to delete a single building block from a model:

1. With the mouse, select the "Arrow Tool" from the Tool Bar. Using the "Arrow Tool", select the structure to be deleted.

2. Press the ***Backspace*** or ***Delete*** key to remove the building block .

Note: it is not possible to undelete a building block .

5.5.3 Keyboard Commands in a Dialog Box

The following keyboard commands can be used to manipulate data within a dialog box. Using these commands, you can perform the same actions as with the mouse.

Tab	Serially moves input focus through each field in a dialog box.
Shift+Tab	Serially moves input focus through each in reverse order.
Alt+letter	Moves input focus to the field or group whose underlined letter matches the one typed.
Arrow key	Moves input focus through each field within a group of options.
Enter	Executes the active button (the button with a bold border around it).
Esc	Closes a dialog box without completing the command. (Same as Cancel)
Alt+Down Arrow	Opens a drop-down list box.
Alt+Up or Down Arrow	Selects item in a drop-down list box.
Spacebar	Cancels a selection in a list box.
Ctrl+/	Selects all the items in a list box.
Ctrl+\	Cancels all selections except the current one.
Shift+ Arrow key	Extends selection in a text box.
Shift+ Home	Extends selection to first character in a text box.
Shift+ End	Extends selection to last character in a text box

5.5.4 Mouse Commands in the Tool Bar

Left Mouse Button

Single-Click

A single-click activates the tool or function that is selected.

Double-Click

Presently, double-clicks affect four of the tools in the tool bar: the Plate Tool, Cylinder Tool, Source Tool, and Receiver Tool. When any of these tool buttons are double-clicked, the tool's Default Parameters dialog box is activated.

Right Mouse Button

The right mouse button has no function in the tool bar.

5.5.5 Mouse Commands in the Model Definition Window

Left Mouse Button

The left mouse button is used to draw, select, and edit structures. Its exact function can vary and is dependent on the tool that is selected. For instance, with the "Arrow Tool" selected, the left mouse button can be used to stretch a plate, to move the location of a source or receiver, or to select a building block. With the Plate Tool, the left button is used to draw a new plate. Also, with the Cylinder Tool, the Source Tool, and the Receiver Tool, it can be used to define a new cylinder, source, and receiver, respectively.

Right Mouse Button

The right mouse button provides the user with the ability to switch drawing planes on-the-fly, without ever leaving the Model Definition Window, and thus, without interrupting the definition of a structure.

Clicking the right mouse button changes the plane of motion from the XY-plane to the YZ-plane, from the YZ-plane to the ZX-plane, and from the ZX-plane back to the XY-plane. The drawing plane is indicated in the left side of the Info Window with asterisks next to the two letters of the drawing plane.

Example

Define a square plate that has the coordinates of [0,0,0], [0,10,0], [10,10,10], and [10,0,10] This is a plate that has one side in the XY-plane at Z = 0, and another side in the XY-plane at Z = 10, as shown in Figure 5.5-1.

Step 1: Start in the XY-plane and define the first corner at the origin.

Step 2: Move to X=0, Y=10 and define the second corner; here Z stays constant because movement is still in the XY-plane.

Step 3: To define the third corner, move to X=10, Y=10, and then click the right mouse button to switch the drawing plane to YZ. X will now stay constant at 10 and the location will vary in Y and Z. Move the cursor to Y=10, Z=10 and define the corner.

Step 4: Clicking the right button twice will change the drawing plane back to XY, Z=10, and allow movement to X=10, Y=0. This will define the fourth corner.

Step 5: Double-clicking with the left button on the last corner will automatically close the square.

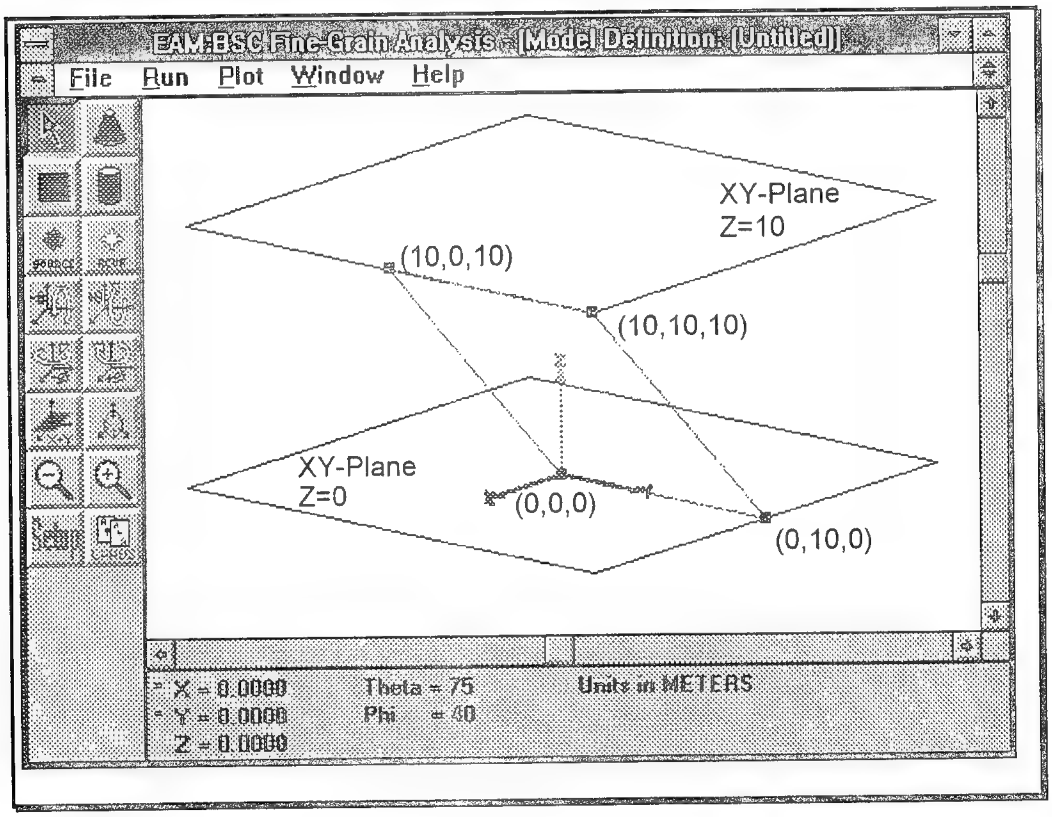


Figure 5.5-1. A Square Plate in a Skewed Plane.

5.6 EAM-BSC TUTORIAL

This section will present a detailed step-by-step tutorial of the major features of EAM-BSC

5.6.1 Opening NEC-BSC Input Files

This section discusses opening a Model Definition Window (MDW) to create a new, or edit an existing, NEC-BSC input file

Creating a New Input File

To create a new input file, select the **File|New** command from the main menu. This will bring up a new MDW for creating an input model. Because only one MDW can be opened at a time, any previously opened window will be closed (this limitation applies only to the MDW). The MDW contains all the available tools for creating a new model.

Opening an Existing Input File

To open an existing input model, select the **File|Open** command from the main menu. This command will bring up a dialog box containing filenames and directories. Selecting a filename and "OK" will cause EAM-BSC to read the model geometry and control lines. The model will be graphically displayed in the drawing area of the MDW and its control lines will stored in the Control Line Editor. Input files do not have to be created with EAM-BSC to be read; any file written in standard NEC-BSC format will be recognized.

Note: EAM-BSC version 1.0 has limitations on the model geometry and control lines it recognizes. Please read the EAM-BSC Capabilities section, Section 5.7, for more information.

5.6.2 Creating and Editing Flat Plates

This section discusses how to set up the "Plate Tool" defaults for drawing multiple plates with identical parameters, how to draw a new plate, and how to edit an existing plate.

Creating a New Plate

Setting Default Plate Parameters

Upon opening a MDW, the default parameters for all new plates are set for perfectly conducting with no dielectric layers. If desired, new default parameters can be specified via the Plate Defaults dialog box before drawing the plate. This dialog box is activated by double clicking on the "Plate Tool" button. Excluding the plate coordinates, it contains all the information required to fully define a plate. This includes plate type and dielectric layer parameters. Any changes made in the Plate Defaults dialog box will apply to all new plates created during that session. Changes made will not apply to any existing plates.

Drawing a Plate

New plate corner coordinates are specified using the Plate Tool. The plate can be drawn in any plane using the mouse with or without the keyboard. Location is changed simply by moving the mouse around in the drawing area, the drawing plane is switched with the right mouse button, and each new corner is defined with a left mouse button click. When used all together, these three techniques will define a plate.

Example

Define a perfectly conducting metal plate with coordinates (0,0,0), (0,2,0), (4,2,0), (4,0,0). This plate is pictured in Figure 5.6-1.

Step 1: Double-click on the "Plate Tool" button to bring up the Plate Defaults dialog box. Define the plate type by selecting the "perfectly conducting metal" option. This will automatically place a "none" in the dielectric layers list box. Select "OK" to save the settings. This only needs to be done once for these settings to apply to all new plates.

Step 2: Because the plate lies flat in the XY-plane, it is easiest to draw while viewing only that plane. Therefore, from the Tool Bar, select the "XY-Plane" button to rotate the model to the XY-plane. This step is not necessary, however, it makes drawing easier.

Step 3: Hit the "H" or "Home" key to place the cursor at the model coordinate system origin. Click and release the left mouse button to define the first corner.

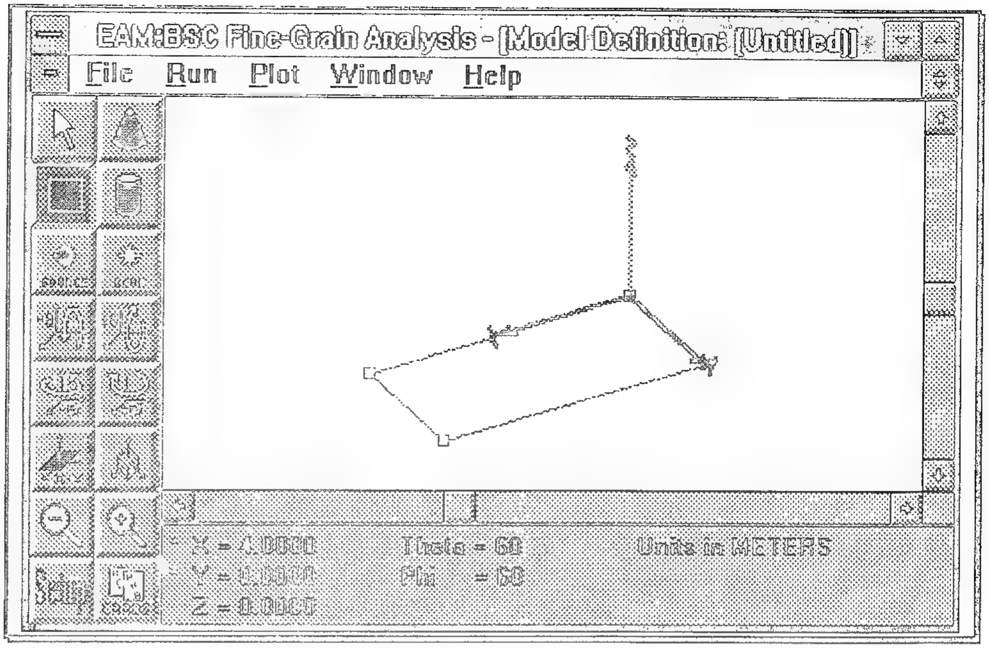


Figure 5.6-1. Example Showing a Single Flat Plate.

Step 4: Move the cursor along the Y axis to X=0, Y=2, and define the second corner by clicking the mouse.

Step 5: Move to X=4, Y=2 and define the third corner by clicking the mouse.

Step 6: Move to X=4, Y=0 and define the last corner. To complete the plate, either move the cursor to the location of the first corner and click the left mouse button, or double click on the last corner location.

Hint: Holding the shift button down will restrict movement to only 1 dimension. When drawing in the XY plane, this will be in the X direction. To draw only in Y, hold the shift button and click the right mouse button. The active direction is indicated in the Info Window with an asterisk next to the coordinate labels.

If this same plate was defined in the XY-plane at Z=5, Step 2 would be preceded by moving the cursor in the ZX- or YZ-planes to Z=5 and skipping Step 3. Or, Step 3 could be modified to also include hitting the "Z" key to increment the plate cursor to Z=5.

Editing an Existing Plate

Modifying the Parameters of an Existing Plate

The Arrow Tool is used to change the parameters of an existing plate. Double-clicking with the arrow tool on the specific plate will bring up that plate's Plate Parameters dialog box, shown in Figure 5.6-2. This dialog is essentially the same as the Plate Defaults dialog except that it also contains the plate's corner coordinates. Any changes made in the dialog box will apply only to that plate.

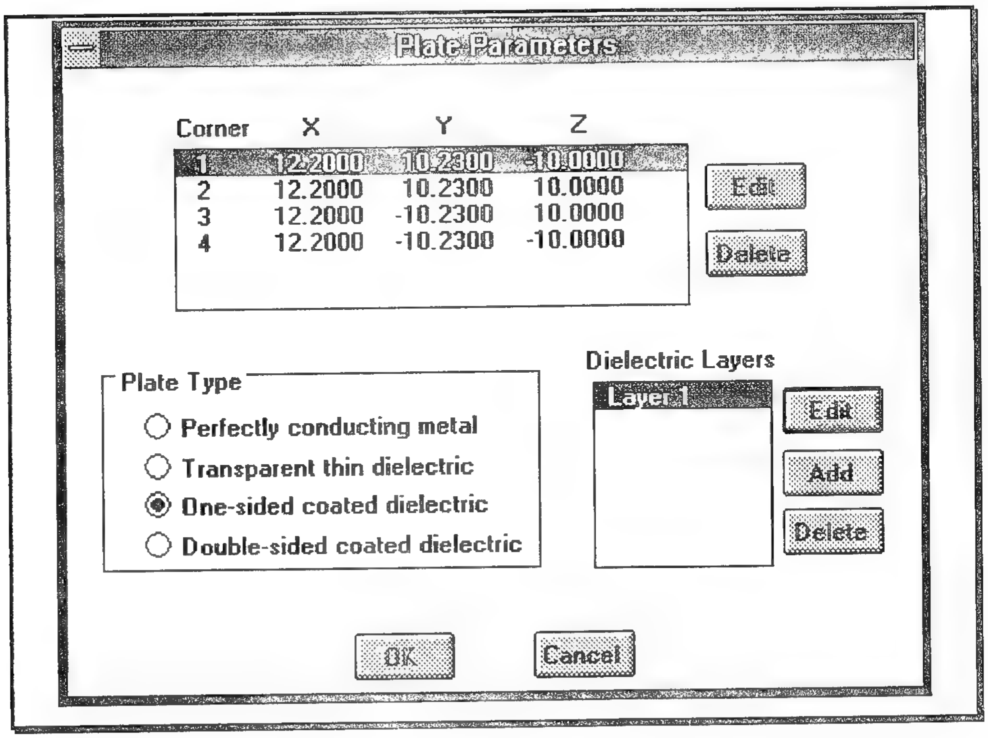


Figure 5.6-2. Plate Parameters Dialog Box.

To edit the coordinates, select the specific corner in the dialog and select the "Edit" button. This will bring up another dialog box for X, Y, and Z to be edited. Corners can also be removed from the plate simply by clicking "Delete". Editing the Plate Type is as simple as selecting the desired option. Dielectric layer parameters are modified by selecting the "Edit" button. All changes are saved only when the dialog's "OK" button is selected. Selecting "Cancel" will discard all changes and return to the drawing area.

Editing Corner Coordinates

Corner coordinates can also be modified in the drawing area. Again using the arrow tool, the corner is selected with the left mouse button. While holding the button down, the cursor can be dragged to the new location

and then released. The coordinate change is automatically entered. The keyboard can also be used to enter a change by selecting a key, "X", "Y", or "Z", while the corner is selected. Hitting the key will move the cursor just like moving the mouse.

Note: consult with the NEC-BSC User's Guide to get more details about the individual plate parameters.

5.6.3 Creating and Editing Cylinders

This section discusses how to set up the "Cylinder Tool" defaults for drawing multiple cylinders with identical parameters, how to draw a new cylinder, and how to edit an existing cylinder.

Creating a New Cylinder

In NEC-BSC, the elliptic cylinder is defined relative to its own coordinate system. The cylinder's length is oriented along the Z-axis, with its end cap's radii specified along the X and Y axes. The cylinder can be rotated to its desired position by specifying the orientation of the cylinder coordinate system relative to the model coordinate system. All aspects of a new cylinder are defined with the Cylinder Tool. Default Cylinder parameters are set from the "Cylinder Tool" button while the cylinder origin is specified using the mouse in the drawing area of the Model Definition Window.

Setting Default Cylinder Parameters

Before drawing a new cylinder, its parameters can be specified via the Elliptic Cylinder Defaults dialog box, shown in Figure 5.6-3. The parameters entered in this dialog box are the cylinder tool defaults and apply to all cylinders that will be created. The Elliptic Cylinder Defaults dialog box is activated by double clicking on the "Cylinder Tool" button. Excluding the cylinder origin coordinates, the dialog box contains all the information required to fully define a cylinder. This includes X- and Y-axis radii, cylinder orientation, and endcap definition.

Any changes made in the Elliptic Cylinder Defaults dialog box will apply to all new cylinders created during the session. Changes made will not apply to any existing cylinders.

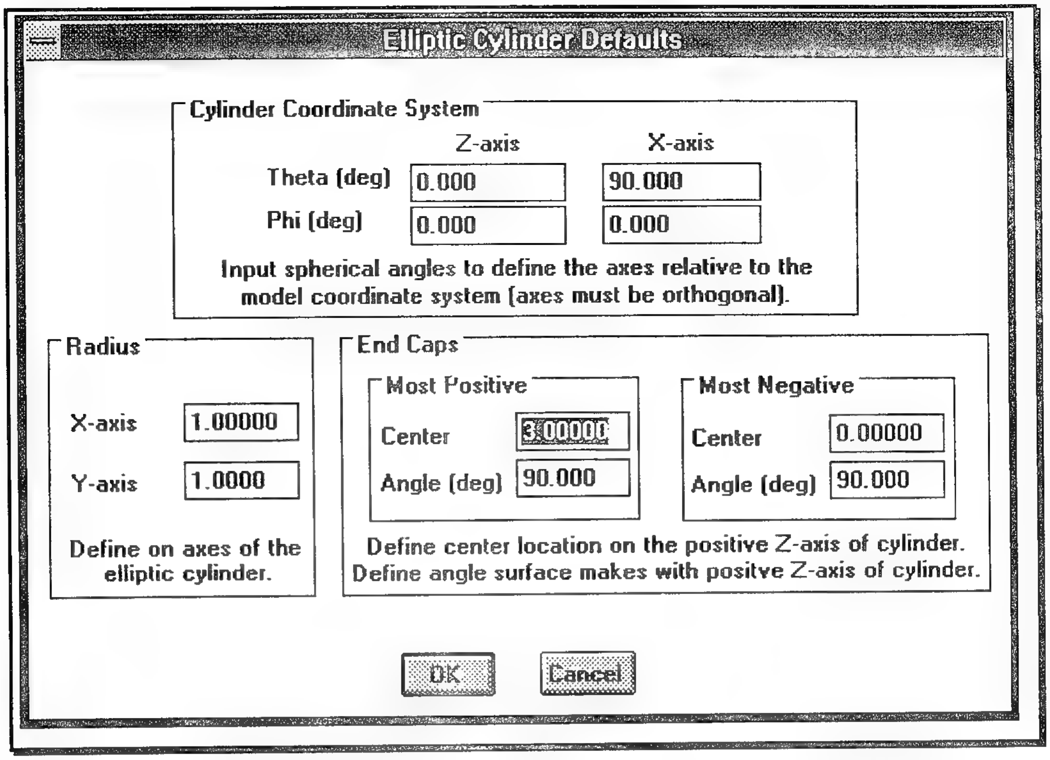


Figure 5.6-3. Elliptic Cylinder Parameters Dialog Box

Drawing a Cylinder

The origin of a new cylinder's coordinate system is specified using the cylinder tool. A cylinder can be drawn in any plane using the mouse with or without the keyboard. Location is specified simply by moving the mouse around in the drawing area, the drawing plane is switched with the right mouse button, and the origin is defined with the left mouse button. When used all together, these three techniques, along with the parameter defaults, will completely define a cylinder.

Example

Define a vertical cylinder at (0,2,0), with an X and Y radius of 2, extending up 5 meters from the ground plane, as shown in Figure 5.6-4..

Step 1: Double-click on the "Cylinder Tool" button to bring up the Elliptic Cylinder Defaults dialog box.

Step 2: A cylinder's length is defined along its Z axis, therefore, for a vertical cylinder, orient the cylinders coordinate system to be the same as the model coordinate system. Set the cylinder's Z-axis to $\underline{\theta=0}$, $\underline{\phi=0}$, and its X-axis to $\underline{\theta=90}$, $\underline{\theta=0}$. This will align both the cylinder and model coordinate systems.

Step 3: Define the X and Y radii to be equal to 2.

Step 4: Set the most positive end cap equal to 5 and make the end cap angle 90 degrees from the Z-axis (the end cap will be flat).

Step 5: For the cylinder to be on the ground plane, set the most negative end cap to 0 and make the end cap angle 90.

Step 6: Select "OK" to save the settings.

Step 7: Press the "H" to set the cursor position to the model origin. Move to X=0, Y=2. Click and release the left mouse button to define the cylinder.

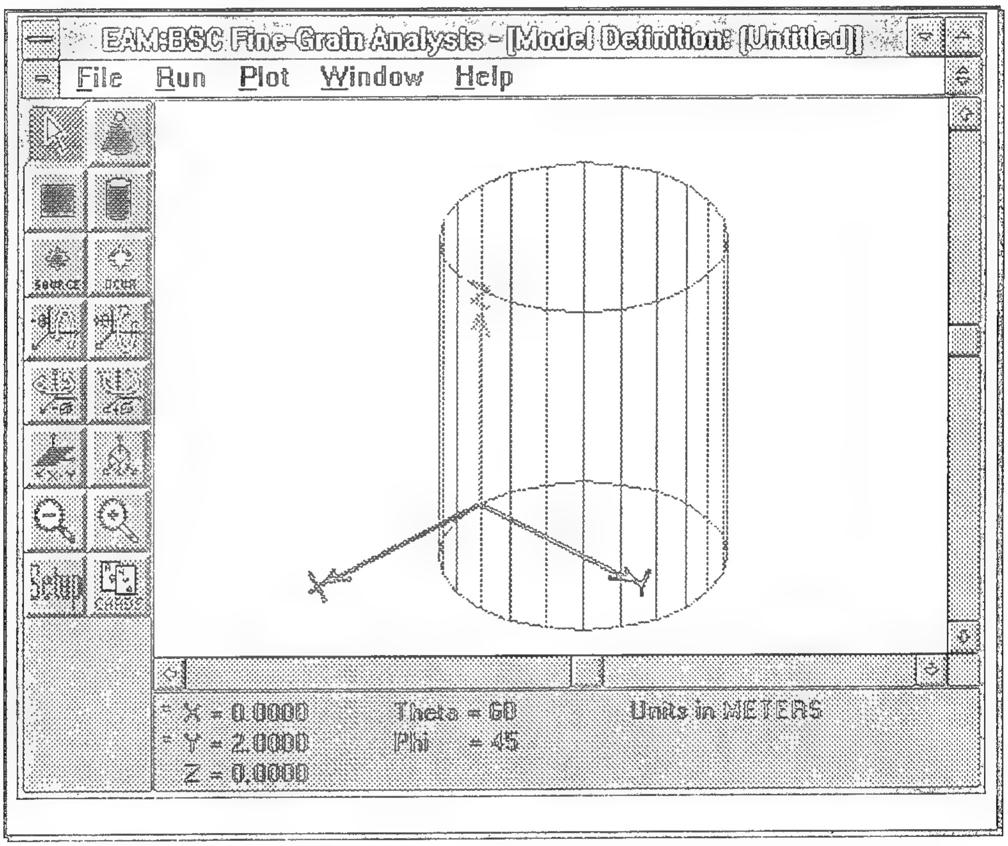


Figure 5.6-4. Elliptic Cylinder at (0,2,0).

Editing an Existing Cylinder

The Arrow Tool is used to edit the parameters of an existing cylinder. Double-clicking with the arrow tool on a specific cylinder will bring up that cylinder's Elliptic Cylinder Parameters dialog box. This dialog is essentially the same as the Elliptic Cylinder Defaults dialog except that it also contains the cylinder's coordinate system origin in the standard

model coordinate system. Any changes made in the dialog box will apply only to that cylinder. The procedures used in defining a new cylinder's parameters are also used here.

Note: consult with the NEC-BSC User's Guide to get more details about the individual parameters.

5.6.4 Defining and Editing Sources

A source must always be specified for NEC-BSC model execution. This section discusses the creation and modification of sources.

Defining a New Source

All aspects of a new source are defined via the Source Tool. Source parameters are set from the "Source Tool" button while the location is specified using the mouse in the drawing area of the Model Definition Window.

Setting Default Source Parameters

New source parameters are specified in the Source Defaults dialog box before drawing the source. This dialog box is activated by double clicking on the source tool. Excluding the source location coordinates, it contains all the information required to fully define a source. This includes element orientation, element type, current distribution, physical dimensions, and excitation. Any changes made by the user in the Source Defaults dialog box will apply to all new sources created during that session. Changes made will not apply to any existing sources.

Drawing a Source

The location of a new source is specified using the source tool. The source can be drawn in any plane using the mouse with or without the keyboard. Location is specified simply by moving the mouse around in the drawing area, the drawing plane is switched with the right mouse button, and the source location is defined with the left mouse button. When used all together, these three techniques, along with the parameter defaults, will completely define a source.

Example

Define a stationary electric half wave dipole at (0,2,0), directed in the X direction with an amplitude of 15 and a phase of 90.

Step 1: Double-click on the "Source Tool" button to bring up the Source Defaults dialog box.

Step 2: First specify the orientation. Set the source element's Z-axis to $\underline{\theta=90}$, $\underline{\phi=0}$, and its X-axis to $\underline{\theta=0}$, $\underline{\theta=0}$. In this case, the source's Z-axis is aligned with the standard model coordinate system's X-axis, and the source's X-axis is aligned with the model's Z-axis.

Step 3: Select the element type as electric.

Step 4: Select a piece-wise sinusoidal current distribution.

Step 5: Assuming lengths are in wavelengths, fill in <u>0.5</u> for length and, to define the receiver as a dipole, <u>0</u> for width .

Step 6: Set magnitude and phase to <u>15.0</u> and <u>90.0</u>, respectively.

Step 7: Select "OK" to save the settings.

Step 8: Press the "H" to set the cursor position to the model origin. Move to X=0, Y=2. Click and release the left mouse button to define the source.

Editing an Existing Source

The arrow tool is used to edit the parameters of an existing source. Double-clicking with the arrow tool on a specific source will bring up that source's Source Parameters dialog box, shown in Figure 5.6-5. This dialog is essentially the same as the Source Defaults dialog except that it also contains the source's location in the model coordinate system. Any changes made in the dialog box will apply only to that source. The procedures used in defining a new source's parameters are also used here.

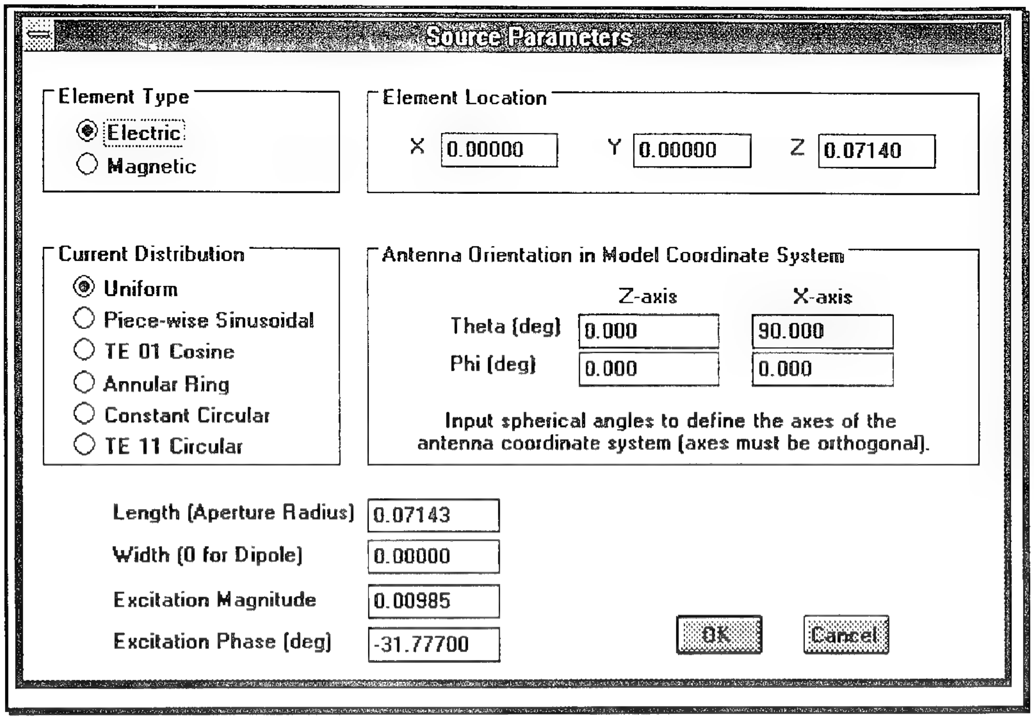


Figure 5.6-5. Source Parameters Dialog Box

Note: consult with the NEC-BSC User's Guide to get more details about the individual parameters.

5.6.5 Defining and Editing Receivers

This section discusses the creation and modification of receivers.

Defining a New Receiver

All aspects of a new receiver are defined with the Receiver Tool. Receiver parameters are set from the "Receiver Tool" button while the location is specified using the mouse in the drawing area of the Model Definition Window.

Setting Default Receiver Parameters

New receiver parameters are specified in the Receiver Defaults dialog box before drawing the receiver. This dialog box is activated by double clicking on the "Receiver Tool" button. Excluding the receiver location coordinates, it contains all the information required to fully define a receiver. This includes element orientation, element type, current distribution, physical dimensions, and excitation. Any changes made in the Receiver Defaults dialog box will apply only to new receivers created

during the session. Changes made will not apply to any existing receivers.

Drawing a Receiver

The location of a new receiver is specified using the receiver tool. The receiver can be drawn in any plane using the mouse with or without the keyboard. Location is changed simply by moving the mouse around in the drawing area, the drawing plane is switched with the right mouse button, and the receiver location is defined with the left mouse button. When used all together, these three techniques, along with the parameter defaults, will completely define a receiver.

Example

Define an electric half wave dipole at (0,2,0), directed in the Z direction with a piece-wise sinusoidal distribution.

Step 1: Double-click on the "Receiver Tool" button to bring up the Receiver Defaults dialog box.

Step 2: First specify the element orientation. Set the receiver's Z-axis to $\underline{\theta=0}$, $\underline{\phi=0}$, and its X-axis to $\underline{\theta=90}$, $\underline{\theta=0}$. This aligns the receiver's axes with the standard model coordinate axes.

Step 3: Select the element type as electric.

Step 4: Select a piece-wise sinusoidal distribution.

Step 5: Assuming lengths in wavelengths, fill in 0.5 for length and, to define the receiver as a dipole, 0 for width .

Step 6: Set magnitude and phase to 1.0 and 0.0, respectively.

Step 7: Select "OK" to save the settings.

Step 8: Press the "H" to set the cursor position to the model origin. Move to X=0, Y=2. Click and release the left mouse button to define the receiver.

Edit an Existing Receiver

The arrow tool is used to edit the parameters of an existing receiver. Double-clicking with the arrow tool on a specific receiver will bring up that receiver's Receiver Parameters dialog box, shown in Figure 5.6-6. This dialog is essentially the same as the Receiver Defaults dialog except that it also contains the receiver's location in the model coordinate system. Any changes made in the dialog box will apply only to that receiver. The

procedures used in defining a new receiver's parameters are also used here.

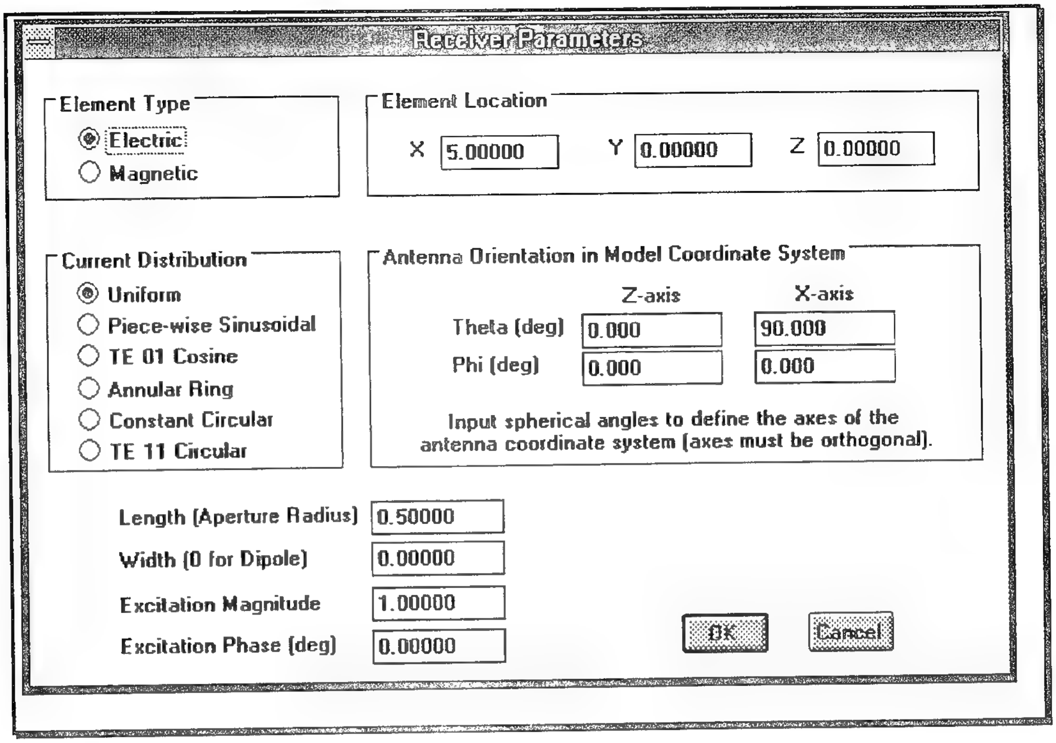


Figure 5.6-6. Receiver Parameters Dialog Box

Note: consult with the NEC-BSC User's Guide to get more details about the individual parameters.

5.6.6 Defining and Editing Model Control Lines

The Control Line Editor was designed to help make the specification of control line options more intuitive and simple for all users. The Control Line Editor is activated by clicking on the "Cards Tool" button. The dialog contains two list boxes entitled: Control Line Options and Model Control Lines. The Control Line Options list box lists all the available control lines and the Model Control Lines list box lists the control lines associated with the current model. Although a brief functional description is presented with most of the available options, it is not intended to replace the NEC-BSC manual. Presently, only the lines listed in the Control Line Options listbox are supported by EAM-BSC version 1.0.

Creating a New Model Control Line List

Creating a new control line list is as easy as copying lines from the Control Line Options listbox to the Model Control Lines listbox. Each line

must be added one at a time. To begin, select a specific line from the Control Line Options listbox. Once a line has been selected, highlighted, selecting the ">>Copy>>" button will put a duplicate of that line into the Model Control Line listbox. This process will be repeated for each control line required for the model.

Modifying an Existing Model Control Line List

There are five ways to modify a Model Control Line list: edit line options, add lines, move lines up or down in order, and delete lines.

Editing Control Lines: The first step in editing a control line is to select the specific line from the Model Control Lines listbox. Once the line has been selected, there are two methods to bring up its options dialog box: use the "Edit >>" button, or double click on the line itself. Both of these commands have the same effect. Once the options have been specified, "OK" should be selected. This will retain any changes made to the line's options. Note that some control lines do not have any options to select and a beep is given to notify you that it cannot be edited.

Adding Control Lines: The first step in adding a control line is to select a specific line from the Control Line Options listbox. Once a line has been selected, selecting the ">>Copy>>" button will put a duplicate of that line into the Model Control Line listbox. This copy will contain all the same option settings, if any, as the original line.

Deleting Control Lines: The first step in deleting a control line is to select the specific line from the Model Control Lines listbox. Once the line has been selected, select the "Delete" button. Before any card is deleted, the Control Line Editor requests verification from the user. Only lines from the Model Control Lines listbox may be deleted.

Reordering Line Sequence: The first step in changing a control line's position is to select the specific line from the Model Control Lines listbox. Once the appropriate line has been selected, select the "Line Up" or "Line Down" buttons to change the control line's position.

Modifying Control Line Options List Defaults

The procedure for modifying the default settings of lines from the Control Line Options listbox is similar to editing control lines from the Model Control Lines listbox. Again, the first step is to select the specific line to be edited. Once the line has been selected, there are two methods to

bring up its options dialog box: use the "<< Edit" button, or double click on the line itself. Both of these commands have the same effect. Once the options have been specified, "OK" should be selected. This will retain any changes made to the line's options.

Note: some control lines do not have any options to select. Also, changes made in the Control Line Options listbox will be available for all models, new and existing.

Using a Default List of Control Lines

Many times, a user may have a generic list of control lines that is used as a base set for many models. With EAM-BSC, such a list can be saved as a default list to be used on future models. To save a default list, simply create the list in the Model Control Lines listbox and select the "Set Default List" button. To later implement the default list, select the "Use Default List" button. This will automatically delete all the lines in the Model Control Lines listbox and replace them with the default list. **Note**: Care should be taken when using this option because there is no command to "undo" the deletion of a model control line list.

5.6.7 Save a Model

To save a model, select the **File|Save** menu item. If the file has not been saved before, the Save As dialog box will be brought up and the user will be requested to assign the model a filename. If the model has previously been assigned a name, it will again be saved to that name.

To save a model under a new name, select the **File|Save As** menu item.

All saved models are written to an ASCII file in the standard NEC-BSC format.

5.6.8 Manipulating the Model View

Altering the Viewing Angle of the Drawing Area

There are six buttons in the tool bar used to rotate a model. Two buttons are used to rotate in Theta, two to rotate in Phi, and two to rotate the model to conventional views.

As an example, bring up an existing model. The model will be displayed at $\theta=60$, $\phi=30$. To look at the model from the top, click on the "-θ" button.

The arrow on the button face represents the apparent direction of the model rotation. The "+θ" button will move the model in the opposite direction. The "-ϕ" and "+ϕ" buttons also rotate the model except it is now rotated around the Z-axis. The θ and ϕ rotation increments in degrees can be modified via the "Set Up Tool" button. The resolution of rotation can be adjusted from 1 to 90 degrees.

To quickly bring the model to a plan view, click the "X-Y" button on the tool bar. This will automatically rotate the model so that you are viewing the XY-plane. Clicking the "X-Y" button again will rotate the model to the YZ-plane. Notice that the face of the button is now labeled as "Y-Z". Clicking the same button again will rotate the model to the ZX-plane and also change the face. One more click will return the model to the XY-plane. This button will always rotate the model in this sequence. You can also achieve an isometric view by clicking on the "Isometric" tool button. This will automatically rotate the model to θ=45, ϕ=45.

Varying the Magnification of the Drawing Area

Magnification of the drawing area is controlled with two buttons in the tool bar that look like magnifying glasses: Zoom Out(-) and Zoom In(+). Zoom Out decreases the magnification, allowing a greater area to be viewed. Zoom in increases magnification, providing a view with greater detail.

With an existing model, click on the "Zoom In(+)" button. This will zoom you into the center of the drawing area. Naturally, clicking on the "Zoom Out(-)" button will reduce the magnification of the model in a similar fashion.

Scrolling the Drawing Area

Using the scroll bars on the drawing window, the model position in the drawing area can be shifted left or right, and up or down. With an existing model open, click on the scroll bar arrows and notice how the model is shifted. Also, try clicking in the scroll bar itself. Notice that the shift is much more drastic.

5.6.9 Running an Analysis

To begin an analysis of the active Model Definition Window, select the **Run** menu item. EAM-BSC will automatically save the input file and launch NEC-BSC. The input and output file names are passed to NEC-BSC and the user is notified that the analysis is under way. While the

analysis is running, the cursor will be displayed as a working clock. An important feature of EAM-BSC is that the user can take advantage of Windows™' multi-tasking ability and switch to another application while the analysis is running. The user will be notified with a beep when the analysis is completed.

Previously generated files written in the standard NEC-BSC input format can be read and executed by EAM-BSC. EAM-BSC version 1.0, however, has some limitations on the model geometry and control lines it will recognize. Please read the EAM-BSC Capabilities section for more information.

5.6.10 Viewing NEC-BSC Output Data

Plotting output data with EAM-BSC is as easy as selecting a menu item and specifying a filename to plot. Once a filename is specified, the data is read into memory and plotted. The X and Y axes are automatically scaled and labeled to provide a readable plot. The plotting routine has the ability to differentiate between constant frequency data and a frequency swept data, thus, relieving you of knowing what type of data the file contains.

EAM-BSC does not require any special processing of the NEC-BSC output file. It does not perform any reformatting or editing of NEC-BSC output files. Instead, it reads the NEC-BSC generated files for desired information and plots the data in the form of colored linear plots. NEC-BSC data obtained from pre-EAM-BSC output files, including those generated on a main-frame computer can also be graphically displayed. In other words, huge models can be easily created with the EAM-BSC, transferred to a main frame computer for execution, and then the output file can be transferred back to the PC for graphical display, as shown in Figure 5.6-7. Presently, EAM-BSC version 1.0 will only plot far field data. If a file does not contain any far field data, the user will be instantly notified. An additional feature of EAM-BSC is that you can simultaneously open multiple plot windows for quick and easy comparisons.

To bring up a plot after running an analysis, select the **Plot|Far Field** menu item. This command will bring up a dialog box containing filenames and directories. Selecting a filename and "OK" will cause EAM-BSC to read in the data and display a Far Field Plot Options dialog box. This dialog allows you to specify the plot type and data set desired. These two options are shown in Figure 5.6-8, and are further described below.

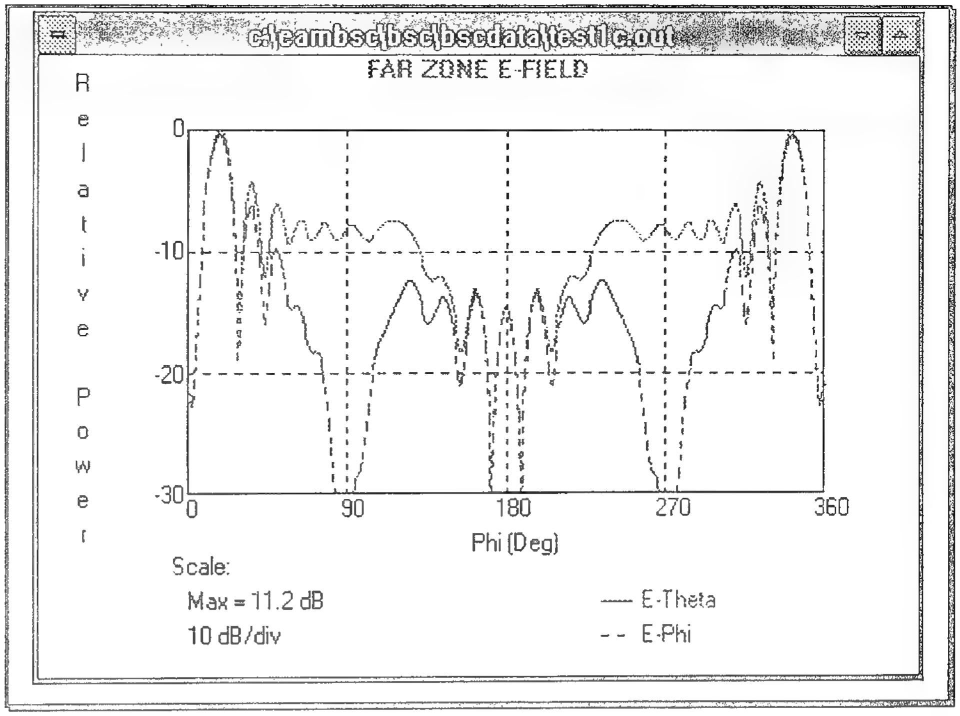


Figure 5.6-7. Far Zone E-Field Plot.

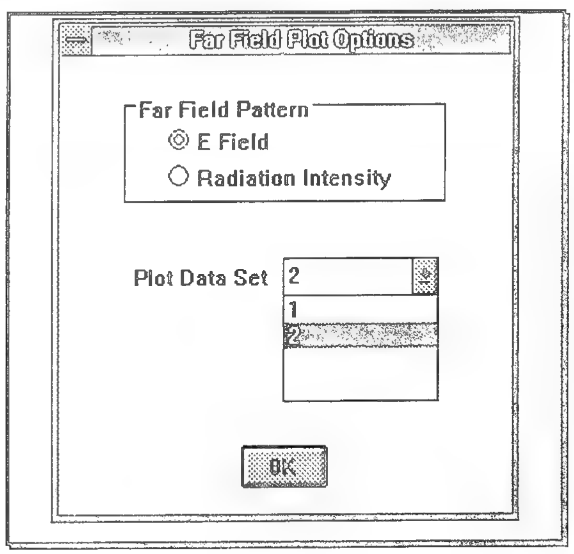


Figure 5.6-8 Far Field Plot Options Dialog Box

Plot Type

Two types of far field data are available for display: E-field or Total Radiation Intensity. You can specify either of these by selecting the appropriate option from within the Plot Options dialog box. For E-field plots, both E-plane and H-plane patterns are always displayed.

Selecting a Data Set to Plot

Immediately after you specify a filename to plot, EAM-BSC scans the file for the number of far field data sets. The number of sets found will then be listed in the Plot Options dialog box under Plot Data Set. This field lets you specify which set to plot by selecting any of the listed numbers.

Plot Options

The plot options mentioned above also apply to open plots. If you wish to plot different data from within the same file, you can specify this with the Plot Options dialog box. Selecting the **Plot|Options** menu item will bring up the Plot Options dialog box for the particular file that is used in the active plot. You can then re-specify the plot options.

5.6.11 Printing

Select the **File|Print** menu item to print. The EAM-BSC print routine is a screen dump so the result will be identical to what is displayed on the monitor.

After selecting **File|Print**, a Print dialog box will be displayed with the following options: *Use Printer Resolution*, *Scaling* and *Number of Copies*.

The *Use Printer Resolution* option will print at printer resolution rather than screen resolution.

The *Scaling* option will increase or decrease the relative size of the printout.

The *Number of Copies* option specifies how many copies are desired.

5.7 EAM-BSC CAPABILITIES

Presently, EAM-BSC is set up to recognize and create input files with only one set of geometry control lines, i.e. geometry and program control lines cannot be intertwined.

The following is a list of the geometry and model control lines supported by EAM-BSC version 1.0. If a line that is not listed occurs in a previously generated input file, EAM-BSC will not recognize it. If that file is then saved by EAM-BSC version 1.0, all unrecognized lines will be eliminated.

Supported Control Lines	Unsupported Control Lines
BP	CC
BF	CF
CG	GR
EN	LP
FM	NX
GP	PR
NC * †	RA
NG * †	RD
NM	RI
NP * †	RM
NR * †	RT
NS * †	SA
OB	SI
PD via PF	SM
PF	TO
PG	UF
PN	PP (obsolete)
RG	VD/VF
SG	VN
TC	VP
TP	
UN*	
US*	
XQ	
XT	

* The control line is recognized in existing input files, however, the user cannot specify this line EAM-BSC.

† The "Next Set of ..." control lines are recognized, but only the geometry lines that follow these lines will be displayed. When the model is saved by EAM-BSC, only the structures that are displayed will be saved.

Note on NEC-BSC

EAM-BSC uses NEC-BSC Version 3.2-3 recompiled to run on a PC running Windows™ in enhanced mode. The only modification made to the NEC-BSC code was a redefinition of the file name it executes on. All algorithms and input/output formats remain unchanged.

6 QUICK-LOOK VALIDATION

Validation provides the user a high degree of confidence that numerically predicted results obtained from computational electromagnetics modeling are correct and reflect accuracy obtained from measurements or accepted analytical approaches. However, in electromagnetics, it is not always possible to know the absolute answer; this is especially true for complex antenna systems where an exact analytical solution may not be possible and measurements are very expensive to perform. Furthermore, the Quick-Look module was designed for solution speed by trading-off accuracy.

Although computer models have no inherent limitation on accuracy other than processing time and storage requirements, we are forced to make various approximations in get an answer in a reasonable amount of time. The SAIC team has been theoretically and computationally developing antennas and electromagnetic systems for decades. This experience base allowed SAIC to choose and develop the most efficient algorithm for each particular antenna module. It is believed that EAM Quick-Look provides the highest degree of accuracy for the quantities estimated, consistent with speed and application requirements.

Inaccuracies arise from a variety of sources which can generally be characterized as one of following:

software errors: originate during the implementation of the algorithms and are typically caused by programming errors.

numerical modeling errors: are due to insufficiently accurate numerical techniques. For example, the computer's word size may be too small to produce accurate results for a matrix inversion algorithm. This type of error results from the computer's need to round off real numbers to a finite number of decimal places.

physical modeling errors: arise from a poor match between the numerical model and the physical world. Assumptions required to make a problem tractable may also make the model unrealistic in a physical sense. The mathematical representation of the antenna may not accurately reflect actual physical system.

user modeling errors: include input data errors that violating limitations intrinsic to the algorithm. Placing two antennas very close

together in the Quick-Look array module may violate the assumption that there is no interaction between elements.

The algorithms used by the Quick-Look module can generally be characterized as either closed-form solutions or numerical approximations. The closed-form solutions were derived either by SAIC or by the references sited in section 2. For antenna modules where no closed-form solutions were readily available, a numerical approximation was employed. For these cases, the moment method was used to predict the current distribution on a wire model of the antenna system.

In what follows, Quick-Look predictions are compared with either a published reference or prediction from the Numerical Electromagnetic Code (NEC). Predictions produced by the modules containing closed-form algorithms derived from published references are compared with data in standard handbooks. These comparisons ensure that the accuracy of the Quick-Look algorithms is consistent with the accuracy of standard antenna engineering references and is thus focused on the validation of software errors. Results from all other Quick-Look modules, including SAIC-derived closed-form solutions and SAIC-derived numerical approximations, are compared with corresponding NEC predictions. These validations are therefore focused on software errors, numerical errors, and physical errors.

6.1 Array Module

The array module uses the standard array factor approach to compute the radiation pattern of a uniform array of identical radiators. Table 6.1-1 compares predictions produced by the array modules with published results. The antenna system consists of a uniform array of seven isotropic radiators with element spacings ranging from 0.1 to 1.0 wavelengths. The results show good agreement with the published results.

Table 6.1-1 Quick-Look Predictions for the Array Module vs. Published Data

Separation	Quick-Look			Published Data		
	3 dB BW (°)	FNBW(°)	FSL	3 dB BW (°)	FNBW(°)	FSL
0.1 λ	79	180		80	180	
0.2 λ	37	88	-12	38	88	-12
0.5 λ	15	30	-13	16	30	-13
1.0 λ	7	14	-14	8	16	-16

FNBW - First Null Bandwidth FSL - First Side-Lobe Level

Figure 6.1-1 is a comparison of the array module's radiation patterns with published results[18]. The figure illustrates (from left to right) the radiation pattern of a half-wavelength dipole, the array factor for two point sources, and the product pattern which represent an array of two dipoles. The dipoles are spaced a quarter-wavelength apart and are excited with a 90° phase difference. These results demonstrate that Quick-Look's array factor and pattern multiplication algorithms were implemented correctly.

Figure 6.1-2 illustrates the radiation pattern produced by a uniform array of 10 half-wavelength dipoles spaced a quarter-wavelength apart and phased 90°. Both NEC and Quick-Look predictions are presented in the figure. Note that the shape of the main lobe shape is very good but the peak gain is slightly off (1.3 dB). This discrepancy exists because the Quick-Look's algorithm, unlike NEC, ignores interaction between adjacent elements.

18 Balanis, C. A. Antenna Theory: Analysis and Design, Harper and Row, NY. 1982

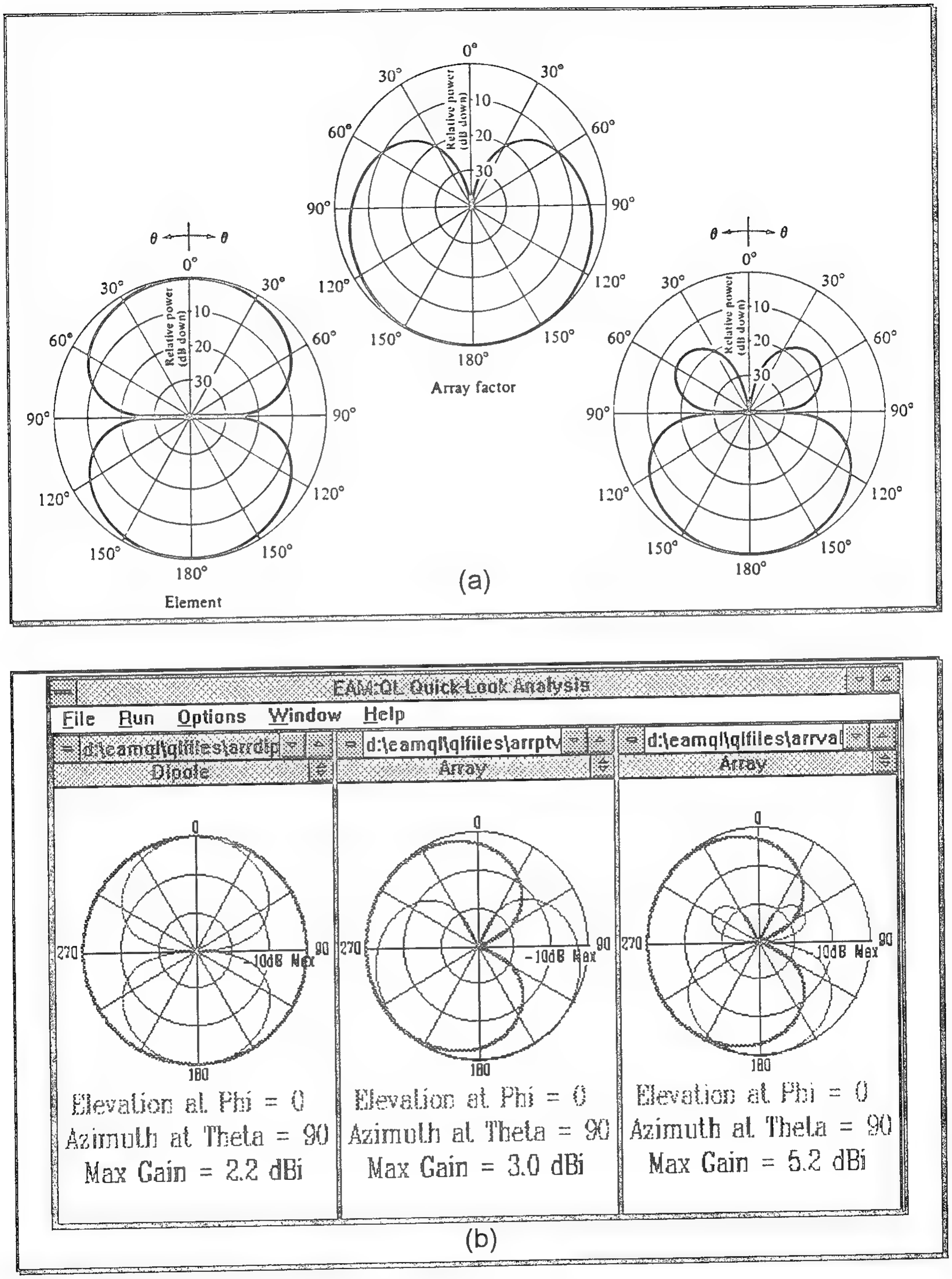


Figure 6.1-1 Array Factor Multiplication by (a) Published Data and (b) Array Module

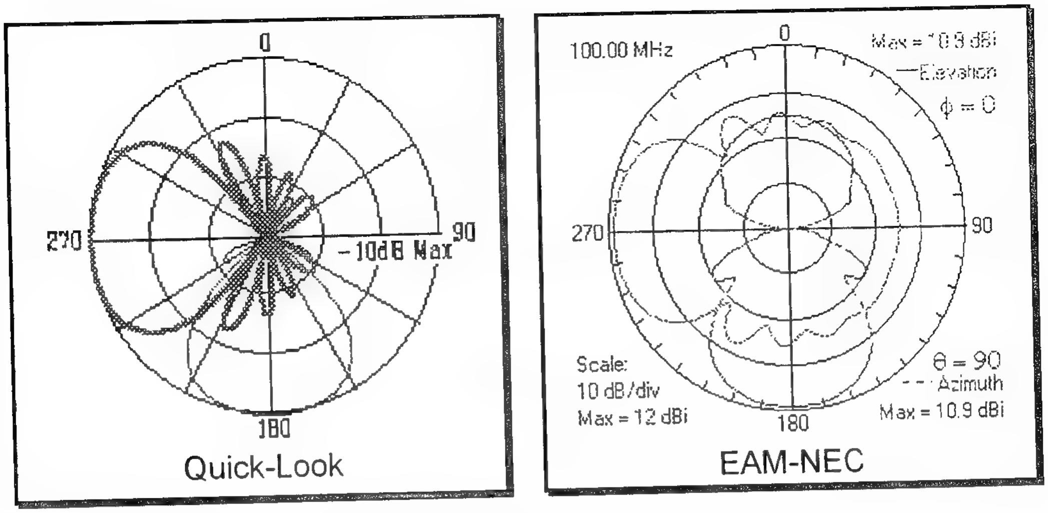


Figure 6.1-2 Radiation Pattern for a 10 Element Dipole Array Comparison Between Quick-Look and NEC

6.2 Cage Dipole Module

A cage dipole is a variation of a conventional dipole where the diameter of the radiating element is increased by using multiple elements excited by one source. In Figure 6.2-1 NEC and Quick-Look predictions of the input impedance are compared for 1, 2, 4, and 8 element cage dipoles of various radii. In both the NEC and Quick-Look cases, the single element cage has the expected impedance of (73+j43)Ω. Overall, the NEC and Quick-Look predictions show good agreement.

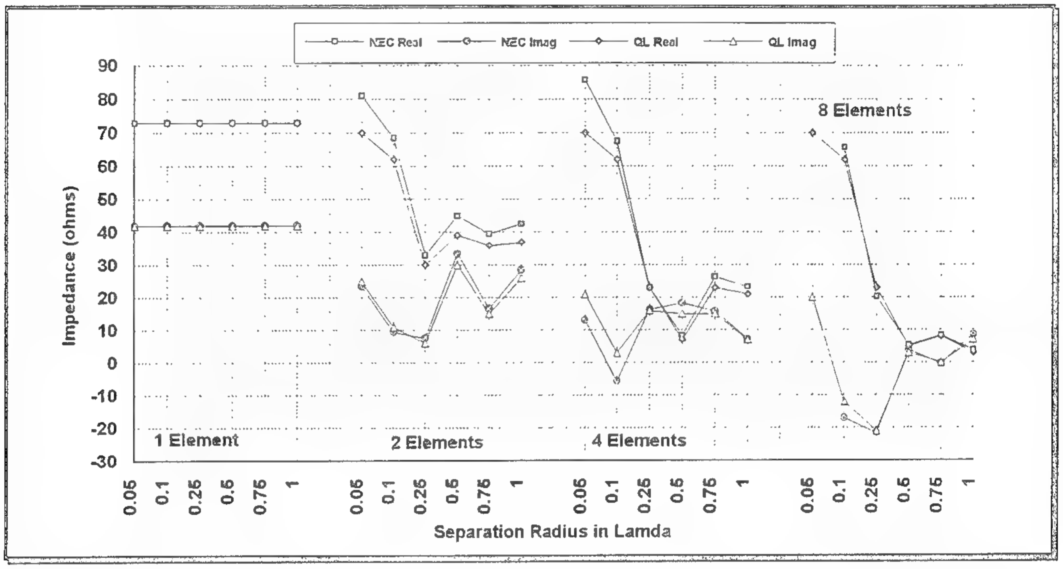


Figure 6.2-1 Input Impedance of Four Cage Dipoles with Different Number of Elements versus element Separation Quick-Look versus NEC

Figure 6.2-2 compares NEC and Quick-Look predictions of the input impedance of a 1m long, 8-element cage dipole with a 1/2m radius. Note that the reactance compares favorably across the entire frequency band, but radiation resistance differs slightly at the high end of the frequency band. This discrepancy is likely caused by the use of a sine wave current distribution by the Quick-Look module.

Figure 6.2-3 is a comparison of the radiation patterns produced by NEC and Quick-Look. The patterns are similar in overall shape with a slight difference (0.2 dB) in peak gain.

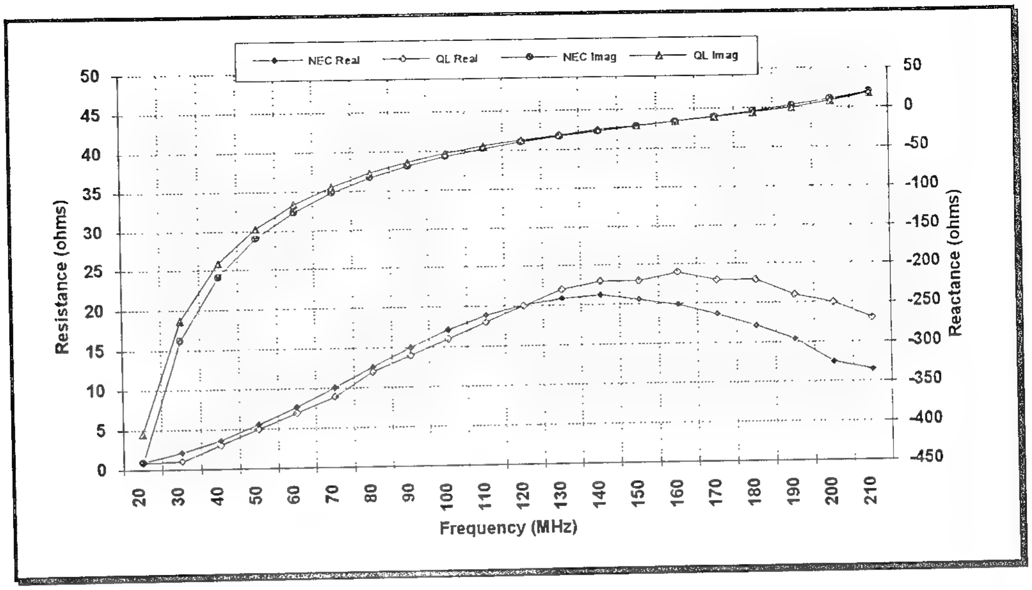
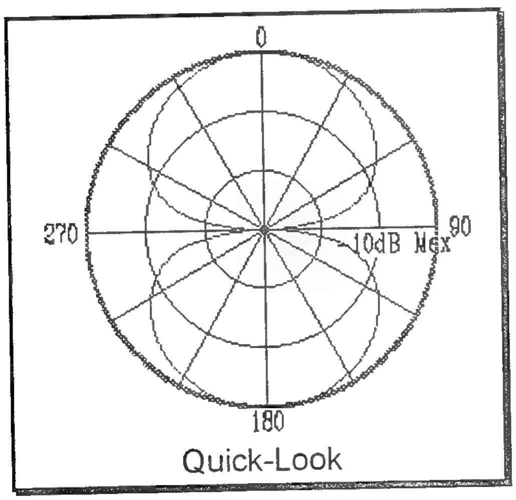
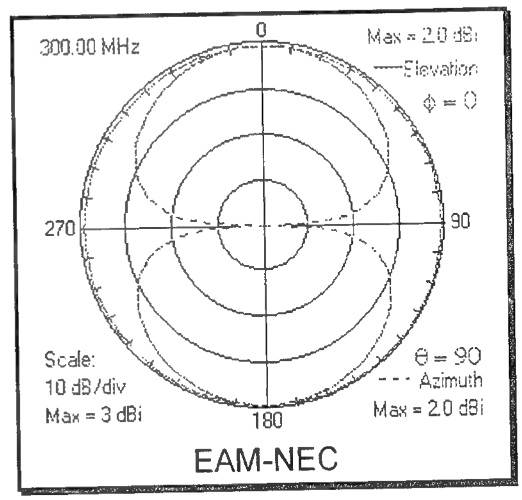


Figure 6.2-2 Input Impedance of a 8 Element Cage Dipole
Quick-Look versus NEC



Quick-Look



EAM-NEC

Figure 6.2-3 Radiation Pattern Comparison between
Quick-Look and NEC

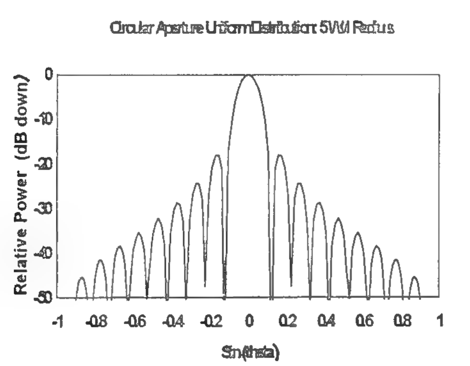
6.3 Circular Aperture Module

This aperture antenna consists of a circular hole cut into a perfectly-conducting, infinite metal plate.

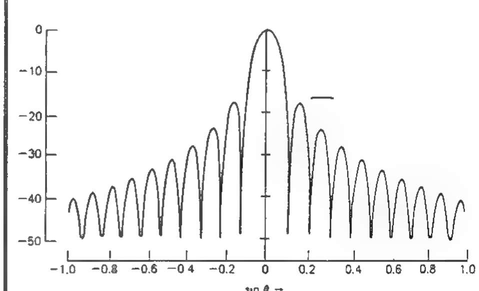
Table 6.3-1 is a comparison of Quick-Look predictions with published results[19]. The H-Plane radiation pattern characteristics are compared at ϕ=0° for a uniform excitation of a 3.0 GHz circular aperture with a radius of 5λ. The first null bandwidth (FNBW), first side-lobe (FSL), and gain all show good agreement. Figure 6.3-1 is a linearly plot of the radiation pattern which demonstrates that the main beam's location and width are consistent with the published results. The levels and beamwidth of the lower side lobes differ slightly.

Table 6.3-1 Uniformly Excited Circular Aperture:
Quick-Look vs. Published Data

	H-Plane (ϕ=0°)	
Parameter	Quick-Look Results	Published Data
3 dB Bandwidth (°)	5	5.8
FNBW(°)	14	14
FSL	-17.9	-17.6
Gain (dBi)	29.9	29.9



Quick-Look
(Data Reformatted for Direct Comparison)



Published Data

Figure 6.3-1 Uniformly Excited Circular Aperture's Radiation Pattern
Quick-Look versus Published Data

Table 6.3-2 is a comparison of Quick-Look predictions and published results[2] for a TE_{11} mode excitation of a 1.5λ radius circular aperture at

19 Stutzman, W., Thiele,G., Antenna Theory and Design, New York: Wiley & Sons, 1981.

3.0 GHz. Note that the H-Plane at ϕ=0° and E-Plane at ϕ=90° agree with published results.

Table 6.3-2 TE_{11} Excited Circular Aperture: Quick-Look vs. Published Data

Parameter	H-Plane (ϕ=0°) Quick-Look	H-Plane (ϕ=0°) Pub. Data	E-Plane (ϕ=90°) Quick-Look	E-Plane (ϕ=90°) Pub. Data
3 dB BW (°)	25	24.6	19	19.4
FNBW(°)	68	65.3	48	46.6
FSL	-28.9	-26.2	-17.6	-17.6
Gain (dBi)	18.7	18.7	18.7	18.7

Figure 6.3-2 is a linear plot of the radiation pattern produced by the circular aperture antenna of Table 6.3-2. The 3D pattern is severed through the ϕ=90° plane for comparison with Quick-Look. The Quick-Look output displays a full 360 degree sweep in elevation, which shows a bi-direction beam.

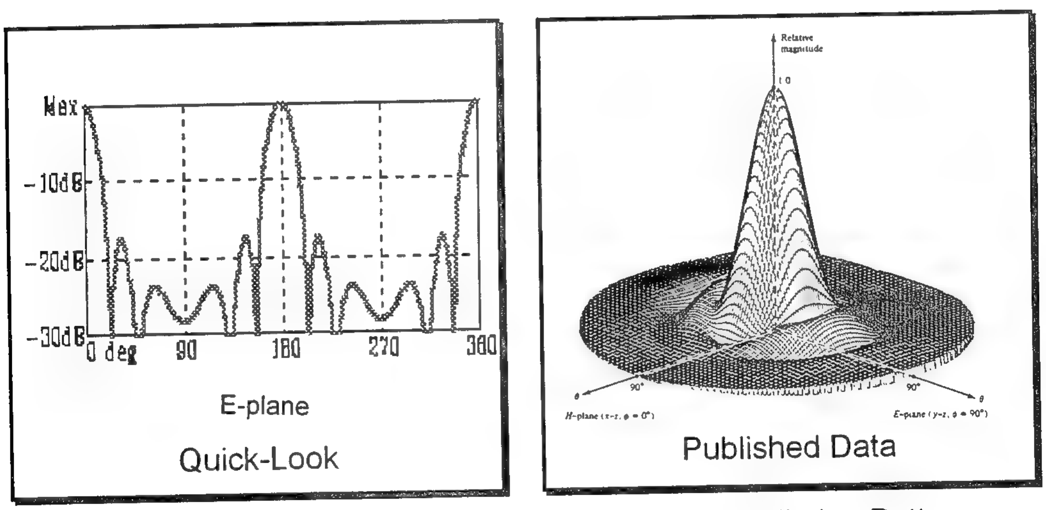


Figure 6.3-2 TE_{11} Excited Circular Aperture's Radiation Pattern
Quick-Look versus Published Data

The curtain array consists of a number of half-wavelength dipoles oriented parallel to the Y-axis and in the YZ plane. The elements are fed in phase to produce a uni-directional radiation pattern whose main beam points along the positive X-axis. The gain is further enhanced by a perfectly-conducting, infinite screen positioned behind the array.

The curtain array was validated with NEC which cannot accurately represent the infinite reflecting screen. This situation results in a 6 dB difference in gain and a bi-directional pattern in NEC. The Quick-Look predicted radiation pattern for the curtain array with the reflecting screen is uni-directional. Table 6.4-1 displays the validation results for six 100 MHz cases which range from a single dipole to a four-by-four array of 16 dipoles. Note that the NEC predictions compare favorably with the Quick-Look cases without the reflecting screen. When the screen is present we get the expected 6 dB difference in peak gain. Figure 6.4-1 displays the radiation patterns predicted by Quick-Look and NEC for a 3x3 curtain array without the reflecting screen. Note the good agreement in radiation patterns.

Table 6.4-1 Quick-Look vs. NEC Predictions for the Curtain Array

		QL w/ Reflector	QLw/o Reflector	NEC
# of Dipoles	Spacing(m)	Gain (dBi)	Gain (dBi)	Gain (dBi)
1	-	14.2	8.2	8.4
2 Y-axis	$\lambda/2$	17.2	11.2	10.1
2 Z-axis	$\lambda/2$	17.0	11.0	11.6
2Y-2Z	$\lambda/2$	20.1	14.0	13.7
3Y-3Z	$\lambda/2$	23.3	17.3	17.0
4Y-4Z	$\lambda/2$	25.4	19.4	19.0

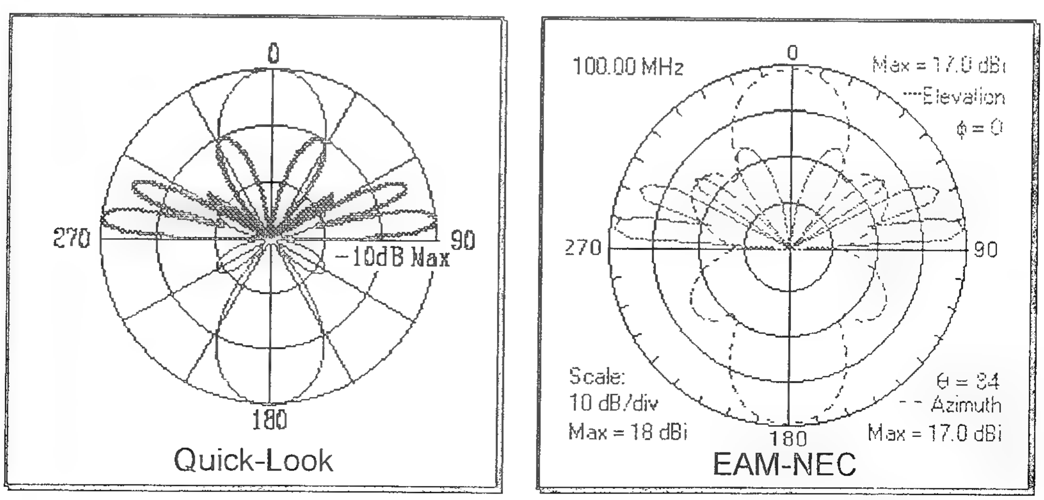


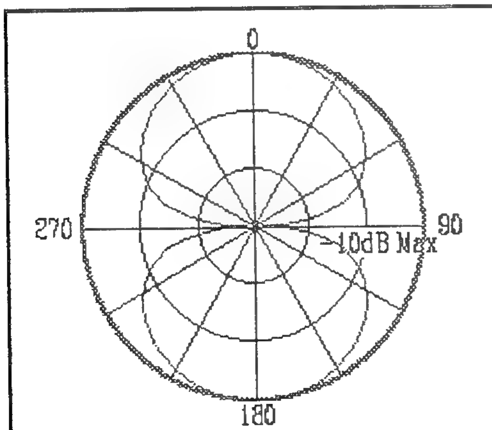
Figure 6.4-1 Radiation Patterns for a Curtain Array without its Reflecting Screen, Quick-Look versus NEC

6.5 Dipole Module

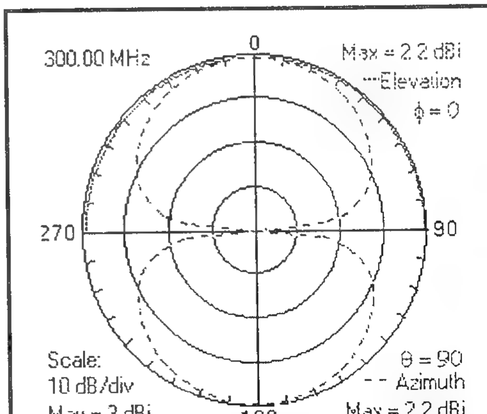
A dipole antenna consists of a single thin wire that is fed at its center by a balanced transmission line. The dipole module was validated by comparing Quick-Look predictions with corresponding NEC results as a function of dipole element length. From an examination of Table 6.5-1 it can be seen that most of the results are fairly consistent with the exception of the anti-resonance case of 3 meters (3λ). For this case, the current at the feed point is nearly zero which results in a large input impedance. Both codes predict large, albeit different, impedances. The different values result from errors associated with modeling very small currents. Figure 6.5-1 illustrates the far field radiation pattern predicted by Quick-Look and NEC for case 1 of Table 6.5-1. Note the good agreement in the overall shape of the patterns.

Table 6.5-1 Quick-Look vs. NEC Predictions for the Dipole

Validation Case	Length (m)	Radius	Freq. (MHz)	Input Imp	Gain (dBi)	E BW (deg.)
Quick-Look	0.5	0.001	300	81+j41	2.2	79
NEC	0.5	0.001	300	83+j47	2.2	78
Quick-Look	0.1	0.001	300	1.8-j1073	1.8	89
NEC	0.1	0.001	300	2.1-j1144	1.8	90
Quick-Look	3.0	0.001	300	965-j870	5.9	21
NEC	3.0	0.001	300	1500-j450	4.7	22
Quick-Look	3.5	0.001	300	140+j42	7.2	20
NEC	3.5	0.001	300	143+j59	5.9	21



Quick-Look



EAM-NEC

Figure 6.5-1 Radiation Patterns for a $\lambda/2$ Dipole Quick-Look versus NEC

6.6 E-Flared Horn Module

An E-flared horn is an aperture antenna that can be thought of as a waveguide with a flared opening at one end. This flared opening is designed to increase the size of the aperture in the E-plane, thus increasing the antenna's directivity in this plane.

The E-flared horn module was validated by comparing Quick-Look predictions with published data[20]. Table 6.6-1 shows the E-horn's specifications and Table 6.6-2 is a comparison of the results. Figure 6.6-1 is a comparison of Quick-Look and published[2] radiation pattern predictions. The patterns demonstrate that Quick-Look is consistent with published results.

Table 6.6-1 E Flared Horn Specifications

E aper Length	2.75 m
H aper. Length	0.5 m
Horn Length	6.0 m
Frequency	300 MHz

Table 6.6-2 Quick-Look Predictions for the E-Flared Horn Module vs. Published Data

Parameters	Quick-Look	Pub. Data
Gain (dBi)	11.1	11.11
E Plane BW	19	18
H Plane BW	101	100
Opt. Length	3.46	
E Plane Err.	56.7	

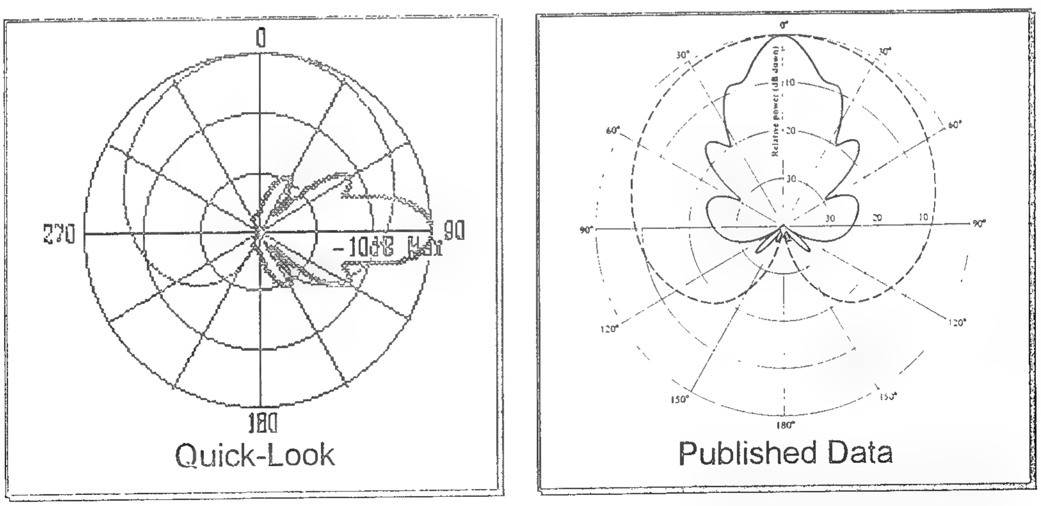


Figure 6.6-1 Radiation Patterns of an E-Flared Horn

20 Balanis, C. A. Antenna Theory: Analysis and Design, Harper and Row, NY. 1982, pp. 541

6.7 Fish Bone Module

The fish bone antenna consists of a series of horizontal dipoles positioned in a planar array parallel to the ground. The elements are connected by a common transmission line which runs d wn the center of the array.

The fish bone module was validated by comparing Quick-Look predictions with NEC results. Two fish bone antennas were examined and the results are shown in Table 6.7-1. Figure 6.7-1 shows the far field radiation patterns predicted by Quick-Look and NEC for case 2. In both cases, Quick-Look demonstrates relatively good agreement with NEC. The gain predicted by the two approaches tends to diverge as the number of elements are increased. This is most likely a result of the Quick-Look assumption that the individual elements don't interact.

Table 6.7-1 Quick-Look vs. NEC Predictions for the Fish Bone

Validation Case	Freq. (MHz)	Number of Elements	Element Length	Element Spacing	Height (m)	Quick-Look Gain (dBi)	NEC Gain (dBi)
Case 1	18.75	10	λ/2	λ/2	8.5	16.0	14.9
Case 2	18.75	21	λ/1	λ/4	17.0	22.8	19.5

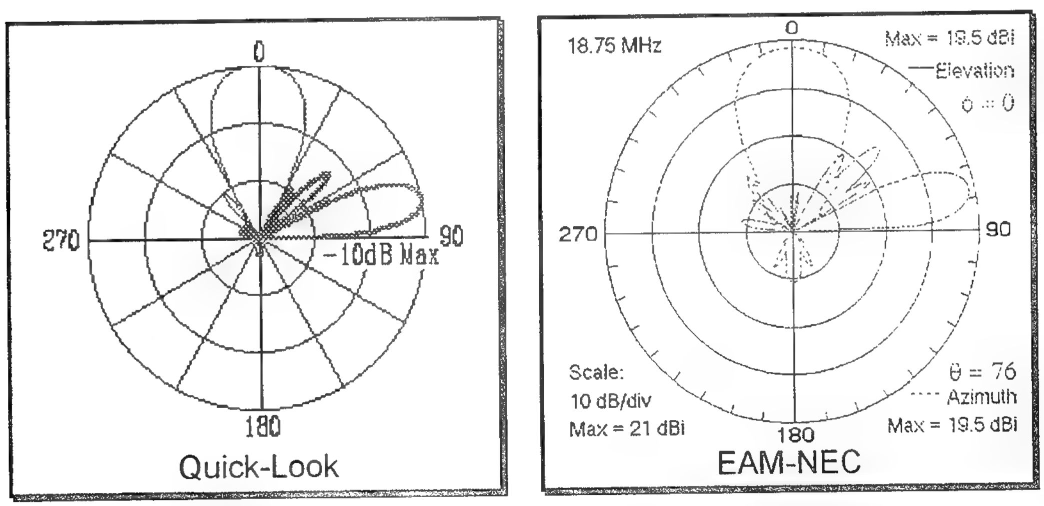


Figure 6.7-1 Radiation Patterns of a 21 Element Fish Bone Antenna Quick-Look versus NEC

6.8 Folded Dipole Module

The folded dipole antenna is a variation of a conventional dipole where two dipoles are positioned parallel to one another and connected at both ends. The performance of the folded dipole antenna is predicted through the use of the method of moments technique.

The folded dipole module was validated by comparing Quick-Look and NEC predictions. Table 6.8-1 display the results for a folded dipole in free space at 30 MHz. Table 6.8-2 displays similar results for a folded dipole 10 meters above a perfect ground. Figure 6.8-1 shows the far field radiation patterns predicted by Quick-Look and NEC for the antenna specified in Table 6.8-2. Overall, the results look good. The radiation patterns look identical for the standard 0.5λ case.

Table 6.8-1 Quick-Look vs. NEC Predictions for the Folded Dipole in Free Space

		Quick-Look		NEC	
Length (λ)	Radius (m)	Input Imp. (Ω)	Gain (dBi)	Input Imp. (Ω)	Gain (dBi)
0.5	0.005	338+j156	2.3	338+j164	2.4
0.75	0.005	355-j1045	3.0	376-j1074	3.0
1.0	0.005	1.6-j51	4.6	1.1+j6.9	6.2
1.0	0.05	1.2-j23	5.4	1.2-j14.3	5.7

Table 6.8-2 Quick-Look vs. NEC Predictions for the Folded Dipole above Ground

		Quick-Look		NEC	
Length (λ)	Radius (m)	Input Imp. (Ω)	Gain (dBi)	Input Imp. (Ω)	Gain (dBi)
0.5	0.005	321+j115	8.3	332+j123	8.4

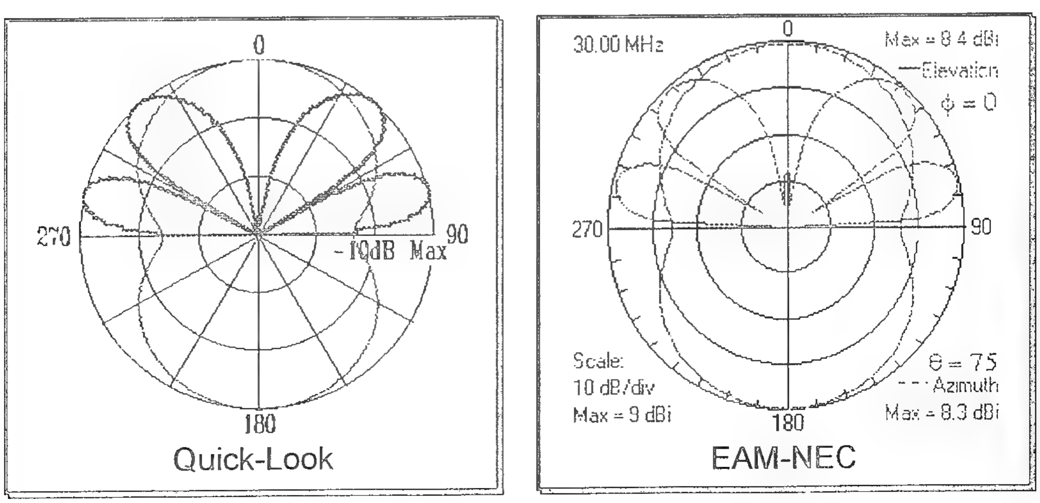


Figure 6.8-1 Radiation Patterns 0.5λ Folded Dipole

6.9 H-Flared Horn Module

An H-flared horn is a waveguide with a flared opening at one end. This flared opening is designed to increase the size of the aperture in the H-plane, thus increasing the antenna's directivity in this plane.

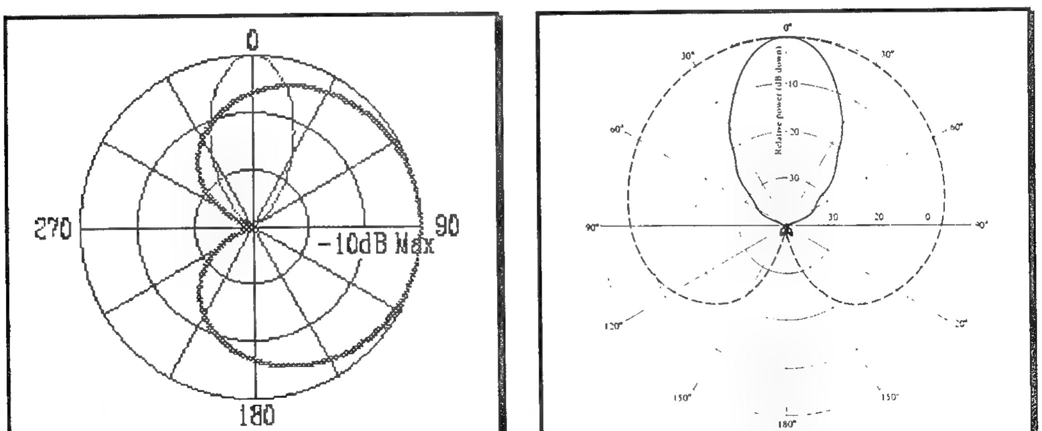
The H-flared horn module was validated by comparing Quick-Look predictions with published closed form solutions[21]. Table 6.9-1 shows the horn specifications and Table 6.9-2 shows the results of the validation. Figure 6.9-1 is a comparison of the far field radiation patterns produced by Quick-Look and published in the open literature. This module uses a closed-form approach to predict the antenna's performance and therefor was only validated to ensure proper implementation of this algorithm. From a review of the tables and the figure it is clear that the Quick-Look predictions are consistent with the published data.

Table 6.9-1 H-Flared Horn Specifications

E aper Length	0.25 m
H aper. Length	5.5 m
Horn Length	6.0 m
Frequency	300 MHz

Table 6.9-2 Quick-Look Predictions for the H-Flared Horn Module vs. Published Data

Parameters	Quick-Look	Published
Gain (dBi)	8.8	8.8
E Plane BW	117°	116°
H Plane BW	21°	20°
Opt. Length	4.2	
H Plane Err.	227°	



Quick-Look

Published Data

Figure 6.9-1 Radiation Patterns of an H-Flared Horn

21 Balanis, C. A. Antenna Theory: Analysis and Design, Harper and Row, NY. 1982

6.10 Log-Periodic Antenna Module

A log periodic is a broadband antenna made up of a coplanar array of varying length dipoles. The individual dipole elements are connected by a transmission line that runs down the center of the array. A single feed point at the center of the shortest dipole element drives the array.

This performance of the LPA is predicted using a comprehensive approach developed by SAIC. Because of this fact, this module was validated to both ensure proper implementation of the algorithm and to ensure that the SAIC algorithm was consistent with other modeling techniques. The performance of a 12-element LPA was predicted by both NEC and Quick-Look and the results are compared below. In Figure 6.10-1, the normalized feed-point current of each of the 12 dipole elements in the LPA is plotted as a function of the driving frequency. Note the three distinct regions in these plots known classically as the transmission region, the active region, and the unexcited region. Because the active region has the largest base currents, it is the primary contributor to the LPA radiation pattern. Note the relatively good agreement between the NEC and Quick-Look predictions of the feed-point current. A more thorough comparison of Quick-Look and NEC-predicted feed-point currents can be found in a recently published paper[22].

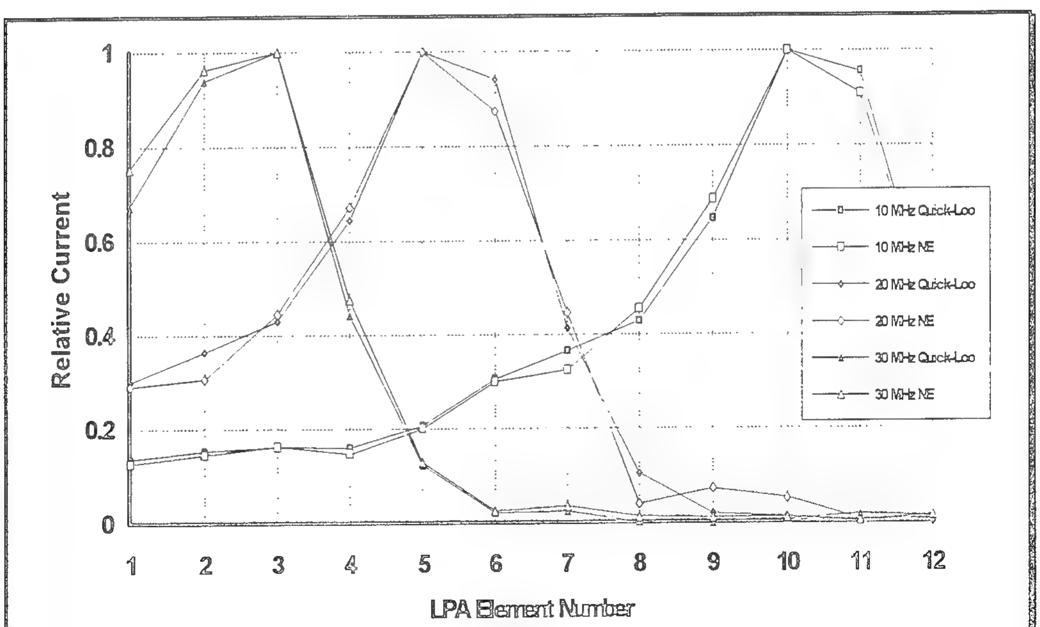


Figure 6.10-1 12-Element LPA Base Currents at 10, 20, and 30 MHz

22 Merrill S.C., Packer, M.J., "A Simplified Approach for Modeling a Log-Periodic Dipole Antenna" 9th Review of Progress in Applied Computational Electromagnetics, Naval Postgraduate School, Monterey, CA 22-26 March 1993

Figures 6.10-2 and 6.10-3 are plots of the Quick-Look and NEC-predicted input resistance and reactance respectively. Again note the good agreement between NEC and Quick-Look.

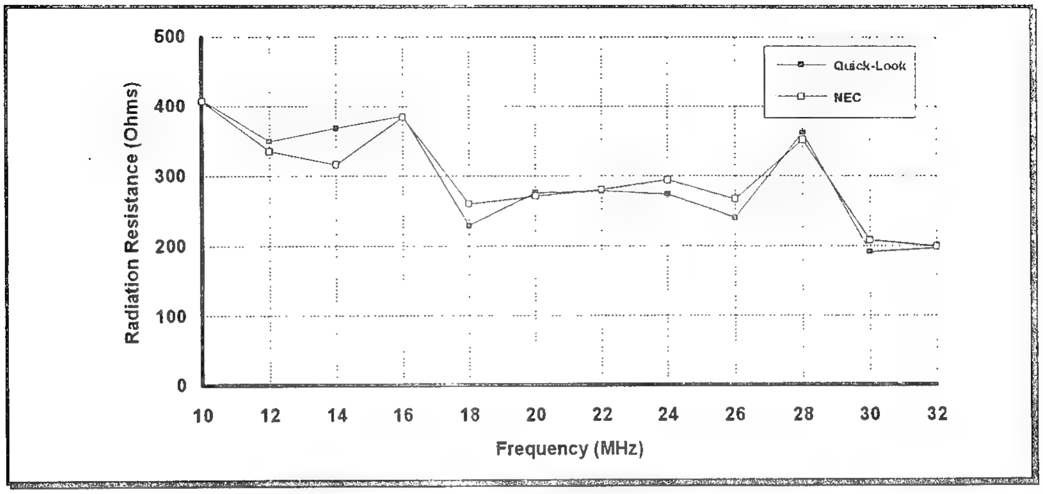


Figure 6.10-2 12 Element LPA Resistance versus Frequency

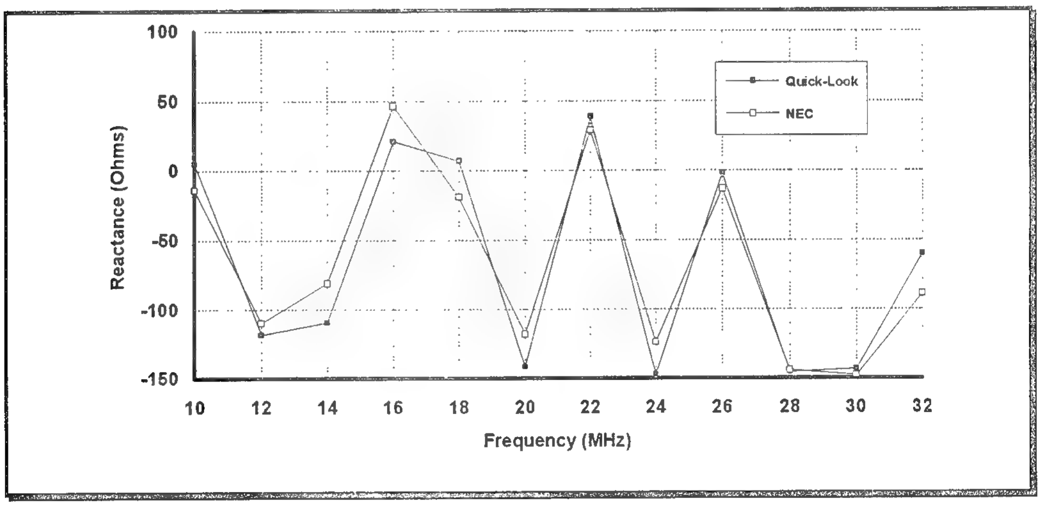


Figure 6.10-3 12 Element LPA Reactance versus Frequency

Figure 6.10-4 compares the radiation pattern of a 12-element LPA at 30 MHz predicted by the two models. Again, NEC and Quick-Look show good agreement.

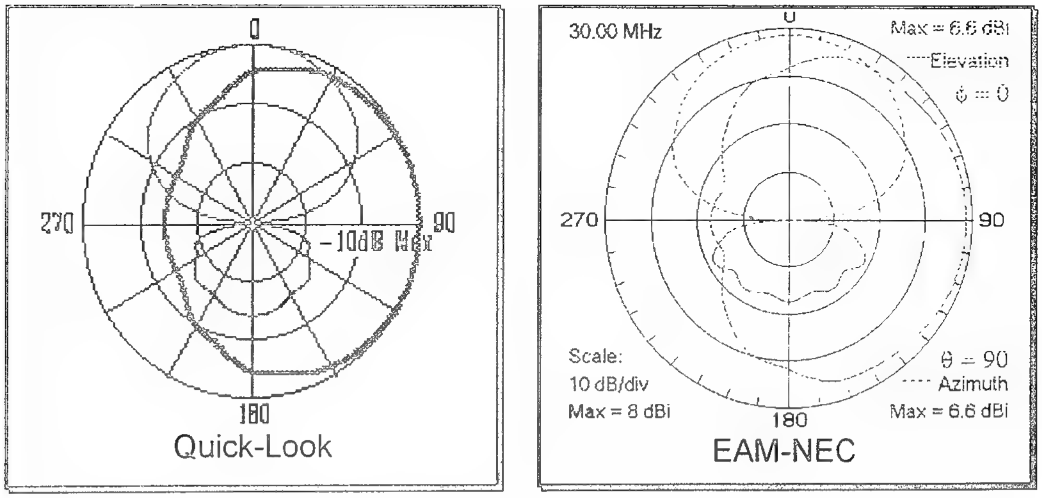


Figure 6.10-4 Radiation Patterns for LPA using Default Values at 30 MHz

6.11 Long-Wire Module

In a long wire antenna, the electromagnetic wave generated by the exciter and imparted to the antenna travels down the antenna and is completely dissipated by a terminating resistor. This situation results in a traveling wave pattern which contrasts the standing wave pattern of a conventional dipole antenna.

This module was validated by comparing Quick-Look predictions with corresponding NEC results. Table 6.11-1 displays these results for a long wire antenna one half a wavelength above a perfect ground. In Figure 6.11-1, the radiation patterns predicted by the two approaches is compared for a long wire antenna with a length of 5 wavelengths. Note the good agreement in the peak gain and in the overall shape of the radiation pattern.

Table 6.11-1 Quick-Look vs. NEC Predictions for the Long Wire Module

Parameters		Quick-Look		NEC		
Length (λ)	Radius (m)	Rad. Res. (Ω)	Gain (dBi)	# Segments	Loading (Ω)	Gain (dBi)
2.0	0.01	168	10.6	30	168	10.2
5.0	0.01	223	13.2	75	223	12.3
10.0	0.01	264	13.9	150	264	13.1

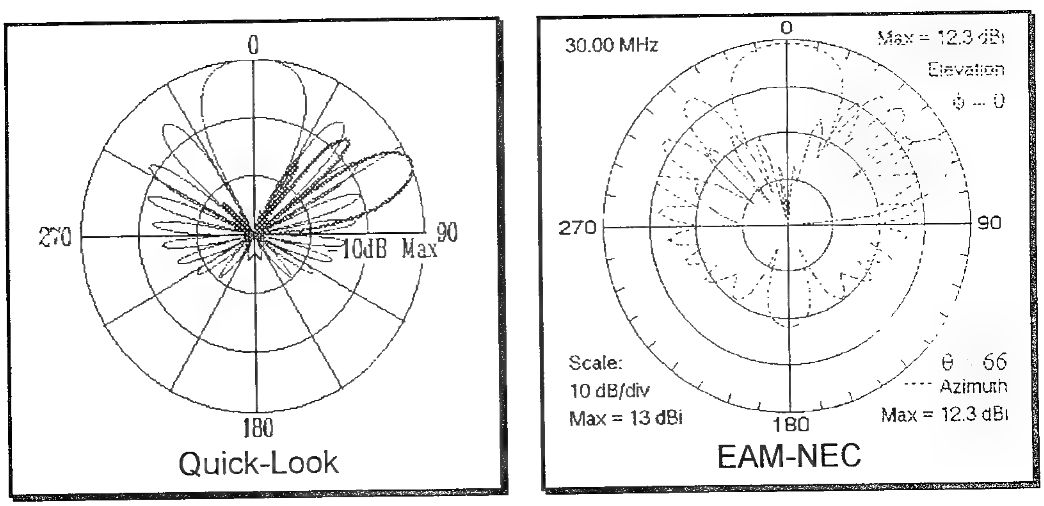


Figure 6.11-1 Radiation Patterns of a Long Wire Above Perfect Ground

6.12 Loop Module

A circular loop is a convenient antenna for many applications. Electrically small loops are employed as receive antennas, while larger loops can be employed as transmit or receive antennas. Because of the differences in performance as a function of loop size, two approaches have been developed to handle the small and large loop cases separately. The performance of small loops is predicted by using a closed form solution which takes advantage of the fact that a small loop is equivalent to a magnetic dipole. Larger loops have a more complex current distribution and their performance is analyzed with the method of moment. The transition between the two algorithms is at 0.03 wavelengths.

NEC results are compared with corresponding Quick-Look predictions to validate this module's performance. Table 6.12-1 contains the specifications and predicted gain for three loop antennas of various sizes. Note the good agreement between NEC and Quick-Look. In Figure 6.12-1, Quick-Look radiation pattern predictions in the transition region between small and large loops is illustrated. Note that the radiation patterns predicted by the two approaches are consistent in the main lobe but differ in the depth of the null.

Table 6.12-1 Quick-Look vs. NEC Predictions for the Loop

Validation Case	Freq. (MHz)	Radius (m)	Radius (λ)	Quick-Look Gain (dBi)	NEC Gain (dBi)
Small	2.0	0.075	0.005	1.8	1.7
Medium	12	0.75	0.03	1.7	1.7
Large	100	0.75	0.25	4.2	4.1

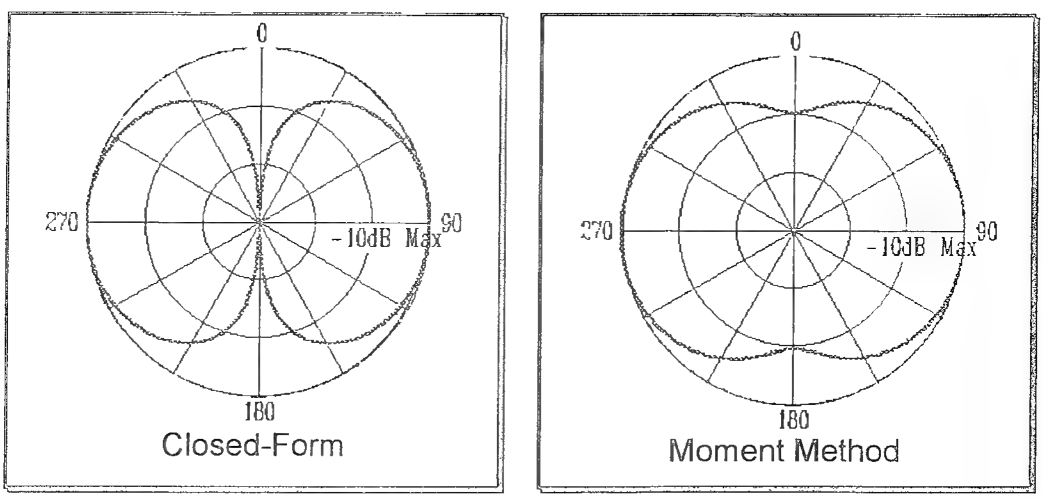


Figure 6.12-1 Radiation Patterns Quick-Look Transition at 0.03λ radius

6.13 Monopole Module

The monopole is simply a thin wire oriented vertically with respect to a ground plane. This geometry produces a vertically-polarized, omni-azimuthal radiated field pattern. A monopole antenna positioned over a perfectly-conducting, infinite ground plane produces a radiation pattern in the upper half-space which is identical in shape to a free-space vertical dipole but has an additional 3 dB of gain. This additional gain is achieved by virtue of the complete reflection of the electric field by the perfectly-conducting, infinite ground plane.

The validation of the monopole was performed by comparing Quick-Look and NEC predictions for a 2.5 meter monopole antenna at different frequencies. Table 6.13-1 displays the comparison for 3 frequencies. Figure 6.13-1 is a comparison of NEC and Quick-Look predicted radiation patterns for a quarter wavelength monopole. These results indicate that Quick-Look and NEC predictions are fairly consistent with the exception of the input impedance at the anti-resonance cases (0.5λ and 2.5λ). In these cases, a near-zero driving-point current creates a large driving-point impedance which is fairly difficult to accurately predict.

Table 6.13-1 Quick-Look vs. NEC Predictions for the Monopole

Case	Length (λ)	Freq. (MHz)	Input Imp	Gain (dBi)	EBW (°)	HBW (°)
Quick-Look	0.25	30	39+j21	5.1	40	360
NEC	0.25	30	40+j23	5.2	40	360
Quick-Look	0.5	60	823-j864	6.9	24	360
NEC	0.5	60	630-j394	7.0	25	360
Quick-Look	2.5	300	266-j350	8.6	16	360
NEC	2.5	300	320+j104	8.3	16	360

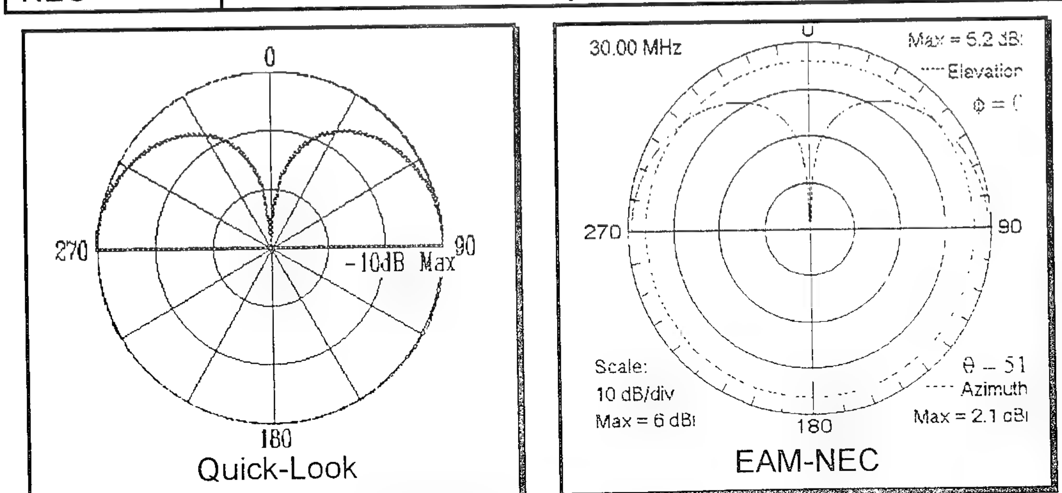


Figure 6.13-1 Radiation Patterns for a Monopole Over Perfect Ground Quick-Look versus NEC

6.14 Parabolic Reflector Module

This antenna consists of a parabolically shaped reflecting surface and a feed element. Energy from the feed element is reflected by the paraboloid and focused into a narrow, collimated beam. Ideally, the feed element would distribute all its energy uniformly over the surface of the paraboloid. In reality, energy is distributed over the dish unequally with some of the energy actually spilling over the edges.

The validation of the parabolic reflector was performed by comparing Quick-Look predictions with a closed-form approach[23]. There is good agreement between the two approaches, which is evident from a review of Table 6.14-1, indicates that the parabolic reflector module is properly implemented.

Table 6.14-1 Quick-Look Predictions for the Parabolic Reflector versus Closed Form Solution

Case	Dia (m)	n	F/D	Freq. (GHz)	Direct. (dB)	Aper. Eff	Taper Eff	Spill. Eff
Quick-Look	10.0	2	0.5	3.0	48.7	75	96	78
Closed Form	10.0	2	0.5	3.0	48.7	75	96	78
Quick-Look	0.25	2	0.3	35.0	37.9	74	74	99
Closed Form	0.25	2	0.3	35.0		78		
Quick-Look	0.25	4	0.3	35.0	36.5	53	53	100
Closed Form	0.25	4	0.3	35.0		54		
Quick-Look	0.25	6	0.3	35.0	35.2	39	39	100
Closed Form	0.25	6	0.3	35.0		42		

[23] Balanis, C. A. Antenna Theory: Analysis and Design, Harper and Row, NY. 1982

6.15 Pyramidal Horn Module

A pyramidal horn is a combination of an E- and an H-flared horn. This antenna can be thought of as a rectangular waveguide with a flared opening.

The validation of the pyramidal horn was performed by comparing Quick-Look predictions with two Published references[24,25]. Table 6.15-1 displays the results for four cases. The first case was chosen because this particular horn has radiation pattern maximums which do not coincide with the horn axis due to phase error taper at the aperture. Figure 6.15-1 displays the radiation pattern for case 1. Note that all Quick-Look results compare favorably with both published references.

Table 6.15-1 Quick-Look Predictions for the Pyramidal Horn vs. Published Data

Cases	Freq. MHz	E Width (m)	H Width (m)	Horn Length (m)	E Gain (dB)	H Gain (dB)	EBW (°)	HBW (°)	E error (°)	H error (°)
Quick-Look	300	6.0	12.0	6.0	12.9	9.7	15.0	55	270	1080
Pub. Data	300	6.0	12.0	6.0			15.5	40		
Quick-Look	300	5.5	2.75	6.0	16.0	15.2	33.0	25	227	57
Pub. Data	300	5.5	2.75	6.0	18.9					
Quick-Look	11000	.1637	.1286	.2963	21.4	21.4	11	15	150	93
Pub. Data	11000	.1637	.1286	.2963	22.6	22.6				
Quick-Look	9300	.1846	.1455	.3398	21.4	21.4	11	15	140	87
Pub. Data	9300	.1846	.1455	.3398	22.1	22.1	12	13.6		

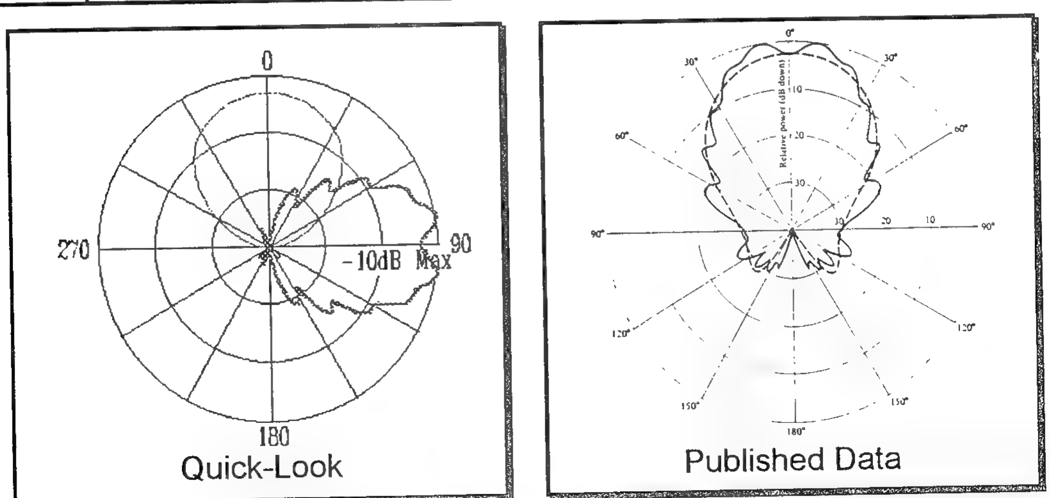


Figure 6.15-1 Radiation Pattern predictions for a Pyramidal Horn Quick-Look versus Published Data

24 Balanis, C. A. Antenna Theory: Analysis and Design, Harper and Row, NY. 1982 pp.571
25 Kraus J.D., Antennas, Second Edition, New York: McGraw-Hill, 1988

6.16 Rectangular Aperture Module

The rectangular aperture antenna consists of a rectangular opening in a perfectly-conducting, infinite metal plate. A rectangular aperture can be excited in a number of different ways. Each excitation method produces a different electric field distribution over the surface of the aperture. The Quick-Look module includes two of the most useful excitation modes; uniform and TE_{10}. In the uniform excitation mode, the electric field is constant in both principal planes (i.e., E, and H). In the TE_{10} mode, the fields are constant in the E-Plane, but sinusoidal in the H-plane.

Table 6.16-1 compares Quick-Look predictions with published data[26] for uniform excitation of two rectangular apertures at 3.0 GHz ($3\lambda \times 2\lambda$ and a $20\lambda \times 10\lambda$). The 3 dB bandwidth, first null bandwidth (FNBW), and gain all compared favorably. Figure 6.16-1 displays the radiation pattern for the 3 $\lambda \times 2\lambda$ case.

Table 6-16-1 Quick-Look Predictions vs. Published Data for a Uniformly Excited Rectangular Aperture

	H-Plane (ϕ=0°)		E-Plane (ϕ=90°)	
X=3λ, Y=2λ	Quick-Look	Pub. Data	Quick-Look	Pub. Data
3 dB BW (°)	17	17	25	25.5
FNBW(°)	38	38.3	60	57.5
Gain (dBi)	18.8	18.8	18.8	18.8
X=20λ, Y=10λ				
3 dB BW (°)	3	2.6	5	5.1
FNBW(°)	6	5.8	12	11.5
Gain (dBi)	34	34	34	34

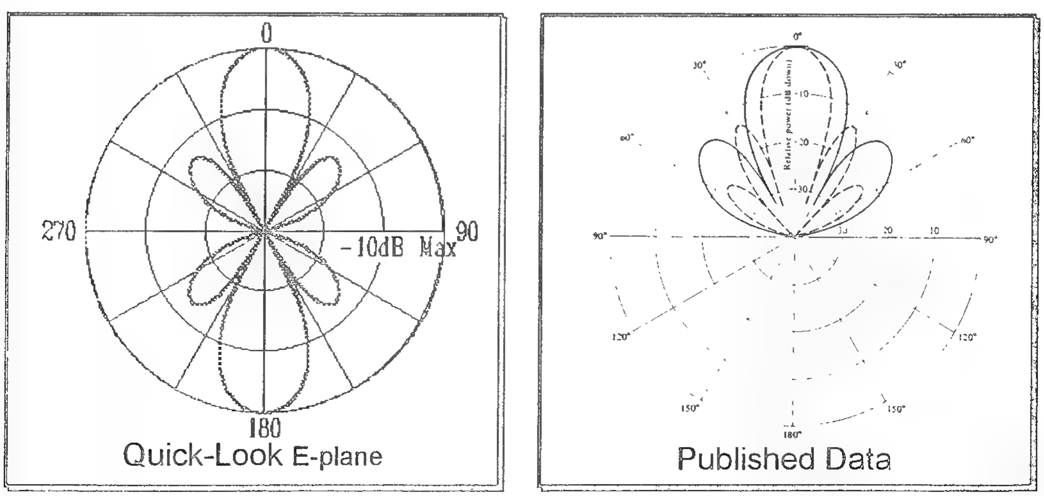


Figure 6.16-1 Radiation Patterns for a Rectangular Aperture Quick-Look versus Published Data

26 Balanis, C. A. Antenna Theory: Analysis and Design, Harper and Row, NY. 1982 pp. 464

In Table 6.16-2 Quick-Look predictions are compared with published data[27] for the same aperture antennas used above with a TE_{10} mode excitation. Note the good agreement in both the H-plane and E-planes.

Table 6.16-2 Quick-Look Predictions vs. Published Data for a TE_{10} Mode Excitation of a Rectangular Aperture

	H-Plane (ϕ=0°)		E-Plane (ϕ=90°)	
X=3λ, Y=2λ	Quick-Look	Pub. Data	Quick-Look	Pub. Data
3 dB BW (°)	23	22.9	25	25.3
FNBW(°)	60	57.3	60	57.5
FSLL (dB)	-23	-25.2	-13.3	-13.3
Gain (dBi)	17.86	17.86	17.86	17.86

In Figure 6.16-2 the radiation pattern predicted by Quick-Look is compared with corresponding Published data[10] for TE_{10} Mode excitation. Note the good agreement between Quick-Look and the published results.

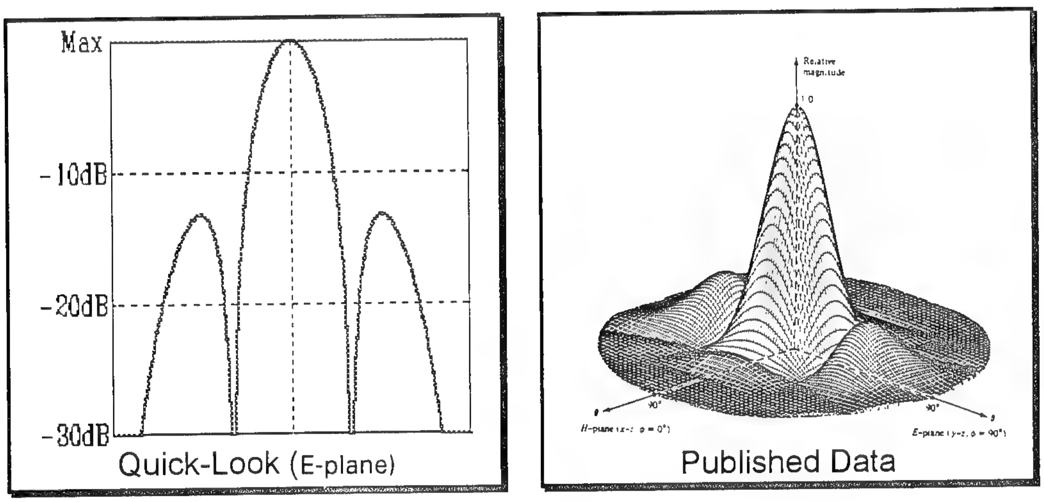


Figure 6.16-2 TE_{10} Mode Excitation Radiation Pattern
Quick-Look versus Published Data

[27] Balanis, C. A. Antenna Theory: Analysis and Design, Harper and Row, NY. 1982 pp. 474

6.17 Rhombic Module

A rhombic antenna is a traveling wave antenna shaped like a rhombus. It can be thought of as two equal length long wire antennas which diverge from the feed point, then bend at their centers and converge at the end point. The antenna is fed at the diverging vertex and terminated with a 600-800 Ω resistor at the converging vertex. When the vertex angles are chosen correctly, this arrangement of long wire antennas forms a uni-directional radiation pattern .

The validation of the rhombic antenna module was performed by comparing Quick-Look results with NEC predictions . Table 6.17-1 displays this comparison for three cases (two wavelengths per side with and without a ground plane and four wavelengths in free space). Figure 6.17-1 displays the radiation pattern for the second case. Note that the Quick-Look module only provides the radiation resistance with no reactance.

Table 6.17-1 Quick-Look vs. NEC Predictions for a Rhombic Antenna

Cases	Length (m)	Apex Half Ang (°)	Height (m)	Freq. (MHz)	Input Impedance (Ω)	E Gain (dB)	H Gain (dB)	E BW (°)	H BW (°)
Quick-Look	20	30	Free	30	579	9.3	9.2	69	23
NEC			Space		650+j74	8.3	8.2	72	20
Quick-Look	20	30	10	30	579	15.2	15.2	15	23
NEC						15.2	15.2	12	24
Quick-Look	40	30	Free	30	750	12.4		27	11
NEC			Space		660+j900	12.1	12.1	26	11

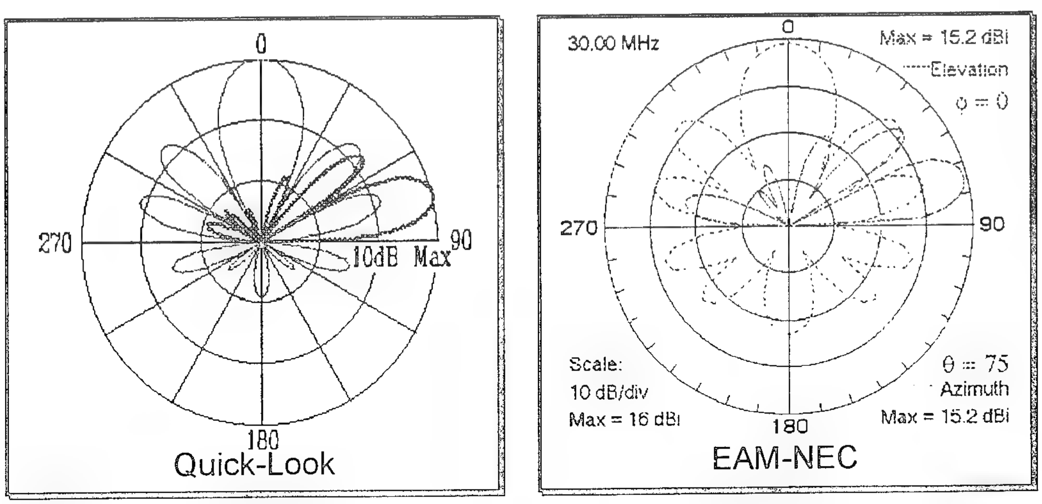


Figure 6.17-1 Radiation Patterns for a Rhombic shown as Case 2 Quick-Look versus NEC

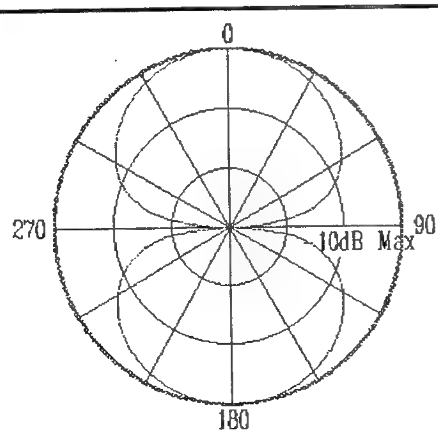
6.18 Thin-Slot Module

A thin-slot aperture antenna is a narrow slot cut into a conducting sheet of metal. The thin-slot antenna is the complementary antenna of a dipole, because the magnetic current in the slot is identical to the electric current on the dipole. The polarizations of the radiated fields between these dual antennas are interchanged. A vertical dipole antenna, for example, has an electric-field pattern that is entirely in the theta (vertical) direction. The electric field of a vertical thin-slot antenna, on the other hand, only has a ϕ (horizontal) component.

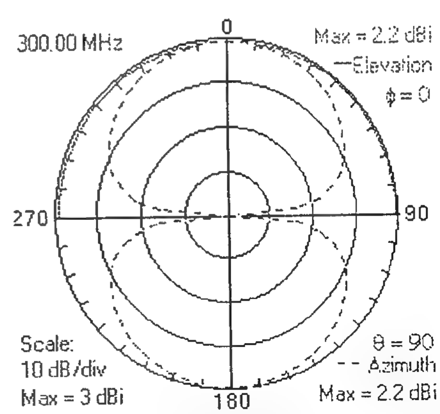
The driving-point impedance predicted by Quick-Look for the thin slot was validated by comparing a published[5] closed-form solution with Quick-Look predictions (Table 6.18-1). Radiation pattern predictions were validated by taking advantage of the duality of the thin slot and the dipole. Figure 6.18-1 is a comparison of a Quick-Look thin slot and a NEC dipole antenna. Note that the polarization shift between the thin slot and a dipole can be seen in the bandwidth columns of Table 6.18-1.

Table 6.18-1 Quick-Look vs. NEC & Published Data for the Thin Slot Module

Cases	Length (λ)	Input Imp (Ω)	E Plane Gain (dBi)	H Plane Gain (dBi)	E BW (°)	H BW (°)
Quick-Look NEC-Dipole	0.25	1.3+j57	1.9 1.9	1.9 1.9	360 87	87 360
Quick-Look Pub Data[28] NEC-Dipole	0.5	362-j210 363-j211	2.2 2.2	2.2 2.2	360 77	77 360
Quick-Look NEC-Dipole	1.0	1.8-j2	3.8 3.9	3.8 3.9	360 47	47 360



Quick-Look



EAM-NEC

Figure 6.18-1 Radiation Patterns for the Thin Slot (Case 2)

28 Kraus J.D., Antennas, Second Edition, New York: McGraw-Hill, 1988, pg. 641

A VEE antenna consists of two long wire antennas which are configured to form a uni-directional radiation pattern. Each of the long wires is terminated with a resistive load to prevent reflections which would result in a standing-wave pattern.

The VEE antenna was validated by comparing Quick-Look predictions with NEC generated results. Table 6.19-1 displays the results for three 30 MHz VEE antennas of different lengths each at a height of 10 meters above a perfect ground. Figure 6.19-1 displays Quick-Look and NEC radiation patterns for case 2. Note the slight difference in the side lobes of the Figure. This difference is expected due to the different methods used to calculate the field strengths.

Table 6.19-1 Quick-Look vs. NEC predictions for the VEE Antenna

Inputs			Outputs			
Cases	Length (m)	Apex Half Angle (°)	E Gain (dBi)	H Gain (dBi)	E BW (°)	H BW (°)
Quick-Look	20	30	10.9	10.9	14	33
NEC	20	30	12.3	12.3	14	32
Quick-Look	40	30	11.7	11.7	12	51
NEC	40	30	12.4	12.4	13	45
Quick-Look	80	15	17.3	17.3	12	19
NEC	80	15	14.1	14.1	12	17

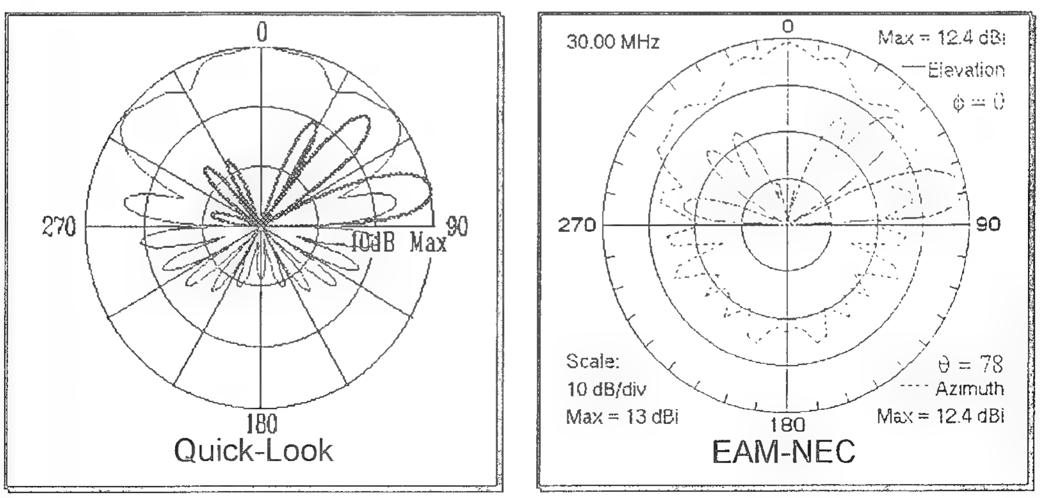


Figure 6.19-1 Radiation Patterns for the VEE (Case 2)
Quick-Look versus NEC

6.20 Yagi-Uda Module

A Yagi-Uda antenna is designed to provide a high-gain, uni-directional radiation pattern with a relatively narrow bandwidth. The antenna consists of a number of dipole elements arranged parallel to one another and in a single plane. Only one of the elements, the feed element, is directly excited via a connection to a transmission line carrying the incoming signal. The others are parasitic elements which are excited by the fields radiated by the feed element.

The Yagi-Uda antenna module was validated by comparing Quick-Look predictions with both NEC and published data[29]. Table 6.20-1 displays the Yagi specifications and the results for six Yagis (3, 4, 5, 6, 7, and 13 elements). Figure 6.20-1 displays the radiation patterns predicted by Quick-Look and NEC for a 15-element Yagi-Uda antenna. Note that the main beams of Figure 6.20-1 compare favorably but the front-to-back (F/B) ratios differ somewhat.

Table 6.20-1 Yagi-Uda Quick-Look versus Published Data

Case	# ele	Space	Lref	Lfeed	Ldir	Gain	F/B	Imp	EBW	HBW
QL	3	0.25	0.479	0.453	0.451	9.6	6.6	18.5-j3.5	55	75
Pub						9.4	5.6	22.3+j15.0	66	84
QL	4	0.15	0.486	0.459	0.453	9.8	8.1	16.7-j4.4	53	71
Pub						9.7	8.2	36.7+j9.6	66	84
QL	4	0.20	0.503	0.474	0.463	10.3	16.7	14.3-j5.9	49	63
Pub						9.3	7.5	5.6+j20.7	54	64
QL	4	0.25	0.486	0.463	0.456	11.2	16.5	14.0-j3.6	47	57
Pub						10.4	6.0	10.3+j23.5	52	60
QL	4	0.30	0.475	0.453	0.446	11.1	9.6	23.1-j5.0	49	59
Pub						10.7	5.2	25.8+j23.2	56	64
QL	5	0.15	0.505	0.476	0.456	8.3	6.2	8.5-j17.5	47	57
Pub						10.0	13.1	9.6+j13.0	62	76
QL	5	0.20	0.486	0.474	0.449	9.9	11.5	8.5-j15.4	45	53
Pub						11.0	9.4	18.4+j17.6	58	68
QL	5	0.25	0.477	0.463	0.442	10.8	7.0	15.8-j11.9	45	53
Pub						11.0	7.4	53.3+j6.2	58	66
QL	5	0.30	0.482	0.453	0.451	9.5	5.2	48.7+j24.4	45	51
Pub						9.3	2.9	19.3+j39.4	40	42
QL	6	0.20	0.482	0.456	0.437	10.4	11.3	19.2-j13.4	45	55
Pub						11.2	9.2	51.3-j1.9	58	68

29 Stutzman, W., Thiele,G., Antenna Theory and Design, New York: Wiley & Sons, 1981, pp. 226

Table 6.20-1 Yagi-Uda Quick-Look versus Published Data

Case	# ele	Space	Lref	Lfeed	Ldir	Gain	F/B	Imp	EBW	HBW
QL	6	0.25	0.484	0.459	0.446	11.0	17.8	27.9-j8.5	43	49
Pub						11.9	9.4	23.2+j21.0	52	56
QL	6	0.30	0.472	0.449	0.437	11.5	8.3	26.7-j8.5	43	51
Pub						11.6	6.7	61.2+j7.7	52	56
QL	7	0.20	0.489	0.463	0.444	10.1	15.2	24.2-j19.8	41	47
Pub						11.8	12.6	20.6+j16.8	52	58
QL	7	0.25	0.477	0.454	0.434	11.4	11.1	21.6-j11.5	43	49
Pub						12.0	8.7	35.9+j21.7	46	50
QL	7	0.30	0.475	0.455	0.439	11.3	9.8	40.8+j1.4	41	47
Pub						12.7	8.7	35.9+j21.7	46	50
QL	13	0.31	0.498	0.466	0.447	13.2	11.0	52.6+j28.8	31	31
NEC						9.3	7.0	85.4+j1.5	24	24

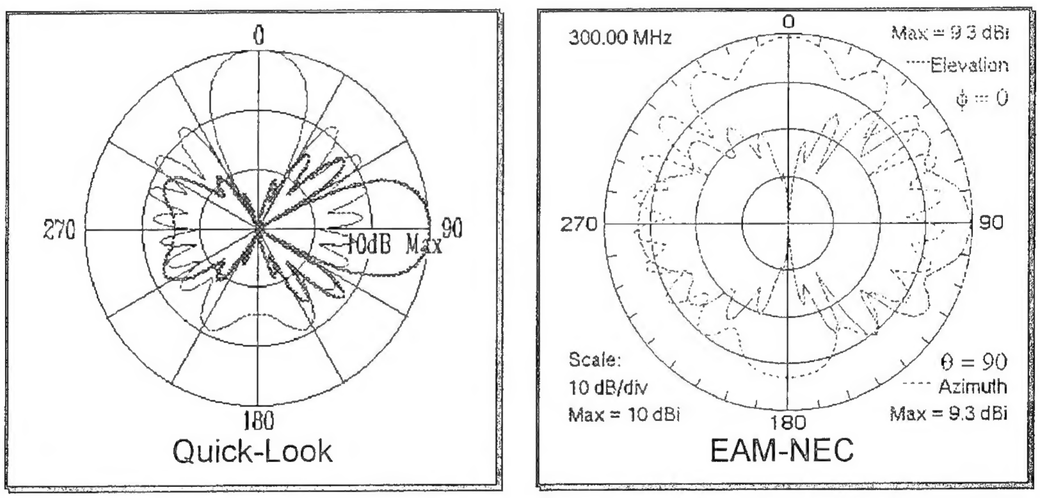


Figure 6.20-1 Radiation Patterns for a 15 Elements Yagi-Uda Quick-Look vs. NEC

7 NOTES

7.1 ACRONYMS, ABBREVIATIONS, AND TERMS

This section contains definitions for terms used throughout the EAM Software Test Plan Document.

A	Analysis
ADW	Antenna Defintion Window
BMP	Bitmap files for antenna visual representations
BSC	Basic Scattering Code
CDRL	Contract Data Requirements List
CSC	Computer Software Component
CSCI	Computer Software Configuration Item
D	Demonstration
DOD	Department of Defense
DOS	Disk Operating System
dB	Decibels
E	Electric (Field or Plane)
EAM	Electromagnetic Antenna Model
EAM:BSC	EAM:Basic Scattering Code
EAM:NEC	EAM:Numerical Electromagnetics Code
EAM:QL	EAM:Quick-Look
FASTC	Foreign Aerospace Science and Technology Center
ELF	Extremely Low Frequency
EM	ElectroMagnetic
FGB	Fine-Grain BSC
FGN	Fine-Grain NEC
FQT	Formal Qualification Test
GTD	Geometric Theory of Diffraction
GUI	Graphical User Interface
H	Magnetic (Field or Plane)
HF	High Frequency

HELP	Help/Tutorial System CSC
HLP	File extension for Help text
HUMINT	Human Intelligence
I	Inspection
I/F	Interface
INP	Filename extension for BSC input files
LPA	Log-periodic Antenna
MB	Megabyte
MDI	Multiple Document Interface
MDW	Model Difinition Window
MoM	Method of Moments
MS-DOS	MicroSoft Disk Operating System
NEC	Numerical Electromagnetics Code
NEC	Filename extension for NEC input files
OUT	Filename extension for BSC and NEC output files
PAS	File extension for Pascal source code
PC	Personal Computer
QL	Quick-Look
RAM	Random Access Memory
RES	Resource file for menus and dialog boxes
RF	Radio Frequency
RL	Rome Laboratories
RTF	Rich Text Format
SAIC	Science Applications International Corporation
SOW	Statement of Work
SRS	Software Requirement Specification
SHF	Super High Frequency
STD	Standard
STP	Software Test Plan
TE	Tranverse Electric
UHF	Ultra High Frequency
USAF	United States Air Force
VHF	Very High Frequency

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